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ACKNOWLEDGMENT

It is a pleasure to commend the far-sighted policy of the Office of Naval Research, with its emphasis on basic research, as a result of which a grant has made possible the continuation of the Coral Atoll Program of the Pacific Science Board.

It is of interest to note, historically, that much of the fundamental information on atolls of the Pacific was gathered by the U S. Navy's South Pacific Exploring Expedition, over one hundred years ago, under the command of Captain Charles Wilkes. The continuing nature of such scientific interest by the Navy is shown by the support for the Pacific Science Board's research programs, CIMA, SIM, and ICCP, during the past eight years. The Coral Atoll Program is a part of SIM.

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Contents

PREFACE AND ACKNOWLEDGMENTS

The Geography of Kapingamarangi as presented in this report is the result of field research conducted by the author and other members of the 1954 Pacific Science Board Expedition to the coral atoll of Kapingamarangi supplemented by published and unpublished materials from previous expeditions and other sources. I wish especially to acknowledge my debt to Kenneth P. Emory of the Bishop Museum in Honolulu from whose study "The People of Kapingamarangi" I have borrowed often and who not only briefed members of the team prior to their departure from Honolulu, but also kindly provided the expedition with a manuscript copy of his study, then unpublished. Carroll J. Lathrop, technician of the Museum, also was helpful in this briefing. William Niering of Connecticut College, whose association I enjoyed in the cooperative mapping of soils and vegetation and of beach and shore characteristics, must share the credit for such data interpreted in this report.

I wish to express my gratitude to those organizations and individuals that made it possible for the expedition to be realized and for my participation in it. This gratitude must go in the first instance to the Pacific Science Board and to its Executive Director, Harold J. Coolidge, for having organized the Atoll Research Program, and to the Office of Naval Research through its Geography Branch for supporting such fundamental research by Contract N7onr-29104 (NR 388 001) with the National Academy of Sciences. I am grateful to Lenore Smith and Ernestine Akers, the secretaries of the Board at Washington, D. C. and at Honolulu, respectively, for their excellent and untiring efforts in arranging for the transportation of the team members and their equipment.

I wish to thank the Wenner-Gren Foundation for providing supplementary funds that enabled me to acquire a substantial motion picture record of the life and activities of the Polynesian people of Kapingamarangi.

The United States Navy and the Trust Territory Administration both have my sincere gratitude for their share in transporting me by air and sea to my destination. Several individuals were especially helpful in making my travel and temporary stops comfortable and interesting. The hospitality of Joshua Tracey and Mrs. Tracey of the U. S. Geological Survey at Guam was much appreciated. At Ponape I became indebted to Mr. and Mrs. Henry Hedges, Mr. and Mrs. Steve Kemske, Mr. and Mrs. Robert Tolerton for their help and hospitality, as well as to Frank Moulton, Robert Halverson and Kan Akatani, all of the District Administration, for their kind cooperation.

Without the cordial cooperation of the people of Kapingamarangi, our two months' stay on the atoll would have been less fruitful and comfortable. The people proved to be most friendly, hospitable and cooperative. My warm appreciation goes to the magistrate, Chief Tuiai, to the island

secretary Rikaneti, to the family of the late King David whose daughter Masako was the expedition housekeeper, and to all the atoll people. I am especially grateful to my personal assistant, Mansa, without whose skill in canoe sailing, intelligence in mapping and constant diligence much of the mapping could not have been accomplished.

Finally, I wish to acknowledge the assistance of Don Schutz, a student at Yale University, in map drafting, and of my wife, Betty, who corrected many mistakes and did the final typing.

I cannot end without expressing my appreciation to my fellow expedition members whose companionship I enjoyed.

Herold J. Wiens
June 1, 1955.

THE SITUATION OF KAPINGAMARANGI

Kapingamarangi, also commonly known as Greenwich Island, is the southernmost of the atolls among the Eastern Caroline Islands and lies in the Equatorial part of the Pacific Ocean (Figure 1)[1]. The atoll is shown on U. S. Hydrographic Chart Number 6042 on a scale of 1:50,340 and is located by the Sailing Directions for the Pacific Islands Vol. 1, 1952 at 1° 4' North and 154° 48' East as measured from the east central part of the reef. The Hydrographic Chart is derived from Japanese sources and reproduces the depth soundings shown on a Japanese chart of the area. Taking the farthest extensions of the atoll rim in each of the cardinal directions, the H. O. Chart shows the northernmost rim extending to 1° 6' 15" N, the southernmost rim extending to 0° 56' 20" N, the westernmost rim reaching 154° 42' 0" E, and the easternmost rim reaching 154° 48' 15" E. However, a comparison of the H. O. Chart with vertical aerial photographs of the atoll indicates that the atoll shape on the chart is as inaccurate as the shapes of the reef islets depicted on the chart. Thus the longitudinal and latitudinal situation given above also must suffer from the same degree of error, and they must be regarded as approximate positions. An adjusted hydrographic chart was made by the present writer on a map based on aerial photos and is shown in Figure 2.

The approximate center of the atoll is 65 miles north of the Equator. The atoll is in the path of the prevailing Easterlies, but it is south of the region of frequent typhoon storms. The Sailing Directions place the next nearest land surface in the atoll of Nukuoro, 164 nautical miles almost due northward. Measured on the A.M.S. 1102 Planning Map for Australasia (dated 1943, scale 1:1,336,000), Ponape lies about 470 statute miles northeast of Kapingamarangi, while Truk lies about 500 statute miles to the northwest. The coast of New Ireland lies about 350 statute miles to the southwest, while Niguria, another Polynesia atoll, lies about 285 statute miles almost due south, the nearest land to Kapingamarangi in this direction. For over 800 miles to the east and over 1,000 miles to the west no land breaks the continuity of the Pacific Ocean. It is obvious that Kapingamarangi has an unusual degree of physical isolation from other lands and peoples.

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1. All figures will be found at the end of Bulletin 49, since they are referred to both in Bulletins 48 and 49.

THE HISTORY OF KAPINGAMARANGI
AND ITS PEOPLE

According to the semi-history recorded in the chants and legends collected by Samuel Elbert on Kapingamarangi,[1] the atoll was discovered by Utamatua, the ancestral chief of the present people on the atoll, a man with magical powers. He was searching the ocean for his wife, Roua, who had swam off to sea in a fit of despondency because of her husband's wandering habits. Utamatua came from the east and found her just before she expired and then sailed on westward to discover the atoll of Kapingamarangi. According to the tale, Utamatua discovered people already on the atoll, but because he demonstrated greater magical power, he was allowed to share the atoll with the predecessors and to become the first ariki or priest of the ancestral cult. He is said to have caused his followers to build up walls or mounds of coral boulders on a raised section of the eastern reef (possibly on old beach rock). This resulted in sand accumulation on the leeward sides to form an islet. Further building up of this islet formed the present main residential islet of Touhou.

When this event is supposed to have occurred cannot be surmised. Emory obtained the names of more than forty ariki.[2] The last 16 are listed in genealogical order and roughly date back, according to Emory, to about A.D. 1800. On the basis of the 120 years occupied by 16 ariki, Emory stated that the list of 40 cannot go back beyond about 300 years. However, he believes that the 40 do not include all the ariki back to the founder Utamatua, and that there is no way to date the founder's arrival on Kapingamarangi. Nukuoro, which has a list of a succession of 101 ariki, would have a genealogical succession going back 700 years if calculations are based upon the average time in office of the 16 ariki of Kapingamarangi. If these two Polynesian atolls 176 nautical miles apart and both a thousand miles west of the main Polynesian realm may be assumed to have been settled at about the same time, then Kapingamarangi must have been inhabited as early as A.D. 1200.

Knowledge of Kapingamarangi first came to Europeans in 1536 when a Spanish vessel despatched by Cortez from Mexico and commanded by Fernão de Grijalvares sighted what appears to have been this atoll. It was named Dos Pescadores (Two Fishermen), implying that there were inhabitants on the atoll. Subsequently, British and French seamen sighted the atoll at various times during the 19th Century, but there are no notices concerning the atoll in the two centuries intervening. This indicates the position of this atoll off the usual route of vessels sailing westward across the central Pacific.

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1. Elbert, Samuel, Linguistic Study of Kapingamarangi, Pacific Science Board, Washington, D. C., 1948, p. 115-122.
2. Emory, Kenneth, The People of Kapingamarangi, carbon of a typed manuscript, Bishop Museum, 1954.

The first account of the inhabitants is that entered in the ship's log of Sir Cyprian Bridge who visited the atoll in 1883.[1] He estimated 150 inhabitants for the atoll under a chief by the name of Ru-Manni. He described them as tall, with a deep-brown colored skin infested with a skin disease of the ring-worm variety, the men wearing a frizzled mop of hair, but the women wearing close-cropped hair.

Although this was the first account of the people by Europeans, a British vessel "Fire Queen" under the command of Captain Hamilton earlier visited the atoll in 1877 and learned of the name of Kapingamarangi (spelled by him "Kapinga Malany"). Perhaps it was at this time that the Kapinga people acquired the fire arms which were observed five years later by Captain Bridge.

That the estimated 150 people in 1883 were probably much fewer than the inhabitants a few decades earlier is inferred by an event that took place about 1870. At this time, according to the German account by Eilers,[2] five big seagoing canoes of Marshallese that had lost their way chanced to land upon the atoll. In the savage manner of the days of pre-European control among the Pacific islanders, for no significant reason the invaders who had landed and made themselves at home on the islet of Hare, suddenly set upon the native inhabitants of that islet and massacred them. From this islet the Marshallese proceeded to Matiro, Werua and Touhou, killing men, women and children without discrimination. On Touhou every living soul was reported to be slaughtered. This tragedy may well have reduced the population by as much as two-thirds or more, since these islets and Ringutoru were the chief inhabited areas. A peace offering of coconuts apparently finally mollified the Marshallese who then stayed on the atoll for 20 months in domination of the area, compelling some of the women to live with them. Finally, the strangers sailed away, taking along some men and women as prisoners, and were not heard of again.

This episode is of significance in relation to the population composition and the number of people that may have lived there at this earlier date. Emory states that the account given him in 1950 indicated that eight canoes had come rather than five, and that the Marshallese had killed a "majority" of the people, including the ariki, Takau, and the secular chief Tikoro. How many men were in the Marshallese party was not indicated, but there must have been a fairly large force for them to overcome the Kapinga people so easily. Probably, too, the Kapinga people had been too isolated to have had much knowledge of or practice in warfare, and they are a gentle, peaceful people. The attack no doubt took the Kapinga people by surprise. In any case, several hundred people must have been killed if thirteen years later the estimate of the population was 150.

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1. Eilers, Anneliese, Inseln um Ponape, Ergebnisse der Südsee-Expedition 1908-1910, Hamburg, 1934, p. 5-6.
2. Eilers, op. cit., p. 130-131.

Another indication of the large population then inhabiting the atoll was given us in 1954 by Chief Tuiai who stated that prior to the Marshallese invasion, Hare and Ringutoru islets were about as thickly covered with houses as Touhou and Werua today. He said that there were so many people on the atoll that many people on Hare would be unknown to people on Ringutoru across the lagoon. Today everyone on the atoll appears to be known to everyone else. However, the earlier lack of mutual acquaintanceship is partly attributable to the fact that few canoes are supposed to have been in existence then, and permission had to be secured of the ariki for the use of canoes and for the chopping down of breadfruit trees for making canoes. As a result, fishing was much restricted and largely confined to the reef, while travel across the lagoon was not common for many of the people. If Hare and Ringutoru with their large areas were settled as thickly as Werua and Touhou are today, and if Werua and Touhou then also were thickly settled, the total population must have been considerably larger than the 426 of 1954 and may have been as large as 500-600.

The Marshallese invasion occurred during the period when the atoll was theoretically under Spanish jurisdiction, although there are no records of the Spanish ever having visited the island during that time. Between 1883 and 1892 some visiting ships brought traders, three of whom, Tu, Harry and Jack Lee successively lived for short periods on the atoll. Lui Patterson, an Englishman, arrived in 1892 and lived on the atoll until his death in August 1899. Two of his five children by the daughter of the ariki Tiahirangi were still living in 1954. Patterson exerted very little influence on the Kapinga people and made no attempt to change their religion, although he urged the abandonment of polyandry because he believed it led to trouble. Shortly after Patterson settled on the atoll, a retired American sea captain called Ned lived for some years at Touhou and had some children by a sister of King Tawehi's wife.[1]

Kapingamarangi became part of the German territories in the Pacific when it was bought from the Spanish in 1899 following the Spanish-American War. The United States apparently showed no interest then in the small island possessions of Spain in Oceania. Small freight and passenger ships of the Norddeutscher Lloyd Company visited the atoll of Kapingamarangi during the German administration, but no white man lived on the atoll from 1914 until after World War II.

During World War I when Japan took over the former German possessions in the Pacific, the Japanese stationed a storekeeper and administrator named Huria ashore on Kapingamarangi. He precipitated a famine during the two-year drought that lasted between 1916-1918 by restricting fishing and the taking of coconuts for food and drink, apparently to conserve coconuts for his copra trade and to have an ample supply of labor on hand. Some 90 people died as a result of the famine. The Japanese subsequently jailed Huria and took some of the people to Ponape to relieve the famine situation.

1. Emory, Kenneth, op. cit.

It was at this time that the Kapinga village of Porokiet (Greenwich Village) was established in the Colonia Port area of Ponape.[1]

This series of events was related to another significant change in the lives of the Kapingamarangi people: the introduction of Christianity by Henry, the son of Mauatoto, the king of Nukuoro. He arrived toward the latter part of the famine in August of 1918, having traveled with a number of Kapinga men returning to the atoll. The Sunday after his arrival, the secular king Tawehi, together with several other men who had been disillusioned in the power of the old pagan religion as led by the ariki, dismantled the sacred part of the already neglected cult house and reconstructed part of it to serve as the Protestant church for the new religion. Henry of Nukuoro, who visited Kapingamarangi in 1954 and whom this writer photographed in Nukuoro in September of this year, during his youth had worked on a British merchant vessel and had become converted to Christianity by the captain. He, seconded by Alfred Patterson, son of Lui Patterson, persuaded the leading men to adopt Christianity.[1]

Tawehi continued as king or chief until his death in 1924, although the Japanese had instituted a system of civil government in Micronesia after the League of Nations mandated Micronesia to Japan in 1920. A succession of local affairs officers were stationed by the Japanese on Kapingamarangi from then on and through the World War II period, although there seldom was more than one Japanese resident on the atoll at one time until the war. From the Japanese the Kapinga people acquired some tastes as well as some tools for carpentering. Thus, the eating of raw tuna soaked in soy sauce was learned from the Japanese, and soy sauce is one of the luxury items demanded as an import.

Immediately prior to the war the Japanese set up a weather station and a sea-plane base at Kapingamarangi with a detachment of over 50 men. According to the Kapinga people, the Japanese service men were not permitted to visit the native residential islets at will and the Japanese military administrator maintained good treatment of the local people during the war period. The sea-plane base was located in the north central part of Hare, while the weather station was located on Nunakita. Both were bombed several times by the Americans during 1943 and 1944 and the installations completely wrecked. Many Japanese are said to have been killed, but no Kapinga people were injured or killed. The Kapinga people had followed Japanese instructions in building underground shelters covered with coconut logs and earth. Several sea-planes wrecked in the war still stood on the beaches of Hare in 1954, while the concrete weather tower on the lagoon side of Nunakita and the wrecked concrete structures and steel radio masts on the seaward side of the same islet are still there, although the latter has become overgrown with vegetation. One of the wrecked concrete foundations had collected rainwater and was swarming with mosquito larvae during the summer of 1954.

1. Emory, op. cit.

A bomb carried by an American B-17 bomber coming in low over Hare on July 7 of 1943 was hit by anti-aircraft fire and exploded, according to Emory,[1] tearing the plane in two and hurling it into the lagoon in shallow water. Native divers recovered the bodies from the wreckage, and the bodies were buried by the Japanese on Hare and subsequently removed to America.

The Japanese vacated the island on July 9, 1944, but it was not until May 3, 1945, that an American seaplane landed off the pass to inquire if any Americans were on the island. On September 22 of 1945, another plane landed off the pass and the next day a screening ship arrived and informed the people that the war with Japan was over and that the American Navy had taken over charge of the atoll. Emory also ascertained that during the earlier part of the war the Japanese had taken some 50 or more Kapinga people to Ponape to help the Japanese, and these added temporarily to the settlement of Porokiet at Colonia. The first American vessel subsequent to the screening ship arrived from Ponape on February 18, 1946, bringing with it some of the Kapinga people from Colonia.

According to Emory, in 1947 the Kapinga colony at Ponape numbered 35 and in 1950 numbered 80. The present writer visited Ponape in 1954 and obtained an enumeration of the Kapinga people at Porokiet at this time which came to 148. This increased migration from the home atoll indicates a growing pressure on the food resources of Kapingamarangi. A total of 426 people on the atoll were enumerated by the island secretary during the summer. In addition, there were 10 Kapinga men on Oroluk Atoll laying the groundwork for a small permanent settlement. Eight Kapinga people were residing at Ngatik and another 10 or so at such places as Kusaie and Nukuoro. Thus the total number of Kapinga people in 1954 was about 602, excluding the 10-15 traveling on the trading vessel "The Lucky".

The following table provides a picture of the population changes on Kapingamarangi since 1883:

Table I

Date	on the atoll	on other islands
1883	150 (estimated) (after Marshallese massacre)	
1890	200 (estimated)	
1910	282 (erroneous, according to Emory)	
1920	300 (Japanese count after famine deaths)	
1925	341 (Japanese count)	
1930	378 " "	
1935	396 " "	
1947	527	46
1950	482	104
1954	426	176 (estimated)

1. Emory, op. cit.

The population prior to the Marshallese onslaught and massacre of 1870 is not known but, according to descriptions by Chief Tuiai, it must have been relatively dense. After the Marshallese disaster there was an accelerated growth interrupted by the famine during the drought of 1916-18. The growth continued until 1947 when the atoll population reached a peak. Thereafter, the atoll population declined through 1954 with increased migration to Ponape and other islands. Part of the attraction luring people away from the atoll has been land made available for homesteading at Ponape and Oroluk. Among the younger men and women, interest in the new cultural atmosphere brought to Ponape by the Americans also has been a factor in the desire to move there.

The population distribution among the islets of the atoll in 1954 was not ascertained. Emory gave it for 1947 as follows:

	Males	Females	Total
Touhou	143	150	293
Werua	87	96	183
Taringa	17	14	31
Matiro	8	5	13
Hukuhenua	4	3	7
Total	259	268	527

Although several other islets have canoe and sleeping houses, as in the case of Hare where there are 29 house structures, they may not be counted as permanent residences, because they are used only for several weeks or months at a time for special purposes, such as when copra is being made. This appears to be the reason why such islets are not included by Emory.

Of the 426 people on Kapingamarangi in the summer of 1954, 202 were male and 224 were female. Some 163 of the total were 14 years of age or under, while 28 people were 65 years or older.[1] On the other hand, of the approximately 150 Kapinga people away from the atoll in the summer of 1954, 70 whose sex was recorded showed a division into 45 males and 25 females. The known sex distribution of about 500 individuals thus shows an almost equal balance between males and females. The 80 or so whose sex was not recorded were mostly young children and babies, and these may also be presumed to be about equally divided in sex. The outward migration from the atoll, however, shows a preponderance of males over females, as one would expect.

1. Trust Territory, Statistical Requirements, Ponape District, Fiscal Year 1954, p. 4.

THE DIMENSIONS OF KAPINGAMARANGI

On its journey to Kapingamarangi, the expedition took along a large scale map of the atoll copied from Kenneth P. Emory's CIMA Report No. 8. Some rough maps for the individual islets on an enlarged scale, which were prepared from rough field maps made by Emory in an earlier expedition, also were taken along. These maps showed many inaccuracies, and the first task undertaken on the atoll by the present writer was the production of more reliable maps for field plotting. A high level vertical aerial photo of the atoll taken by the U. S. Navy Air Photo Section was obtained from Guam and a large scale map of the atoll as a whole on the scale of approximately 1:18,460 was constructed from it, double the scale of the aerial photo. Maps for the individual islets were devised by pacing around them and by plotting on a plane table with the aid of a sight alidade and a Brunton compass, the paces being checked with steel tape initially. Mansa, a Kapinga assistant, made simultaneous pacings with the present writer in order to check any major discrepancies or errors.

The field maps thus made were on a scale of 1 inch to 100 feet from which the finished maps included in this report have been reduced to half the scale (Figures 10-27). On all the smaller islets, error of closure in the traverses proved very small. On the two large islets of Werua and Hare, larger errors of closure required additional surveys including the use of the steel tape to eliminate distortion. It is believed that the final maps show the various islets with a high degree of conformity to actual shapes and relative dimensions as well as to orientation. Owing to the complexity of taro pits on Werua and Hare and to heavy underbrush around parts of the fields, a somewhat lower degree of conformity may be expected for the taro pits on Werua and Hare. A complete resurvey was made of virtually all the taro pits on Werua and on a number of pits on Hare to insure a reasonable order of accuracy. The writer believes that as a result of this survey, much more accurate measurements of areas for islets, taro pits and vegetation zones have been made possible. Map measurements for the different areas are presented in Table II. The land area above water is less than had been previously supposed. In the measurement of the various areas, one set of measurements was made with a hatchet planimeter. A second set of measurements was made by the method of counting squares using squares of 1/10 of an inch for a double check. The figures presented are the result of averaging the two sets for the particular areas concerned.

Kapingamarangi Atoll is an egg-shaped reef completely enclosing a lagoon with the exception of two adjacent passes along the southern rim. The maximum length of the atoll from the outside edges of the coraliferous terrace is 8 statute miles in a SE to NW direction. Its north to south width is 6.3 miles. The total area is 31.7 square miles, of which the lagoon occupies 23.8 square miles and the surrounding reef occupies 7.87 square miles.

Within the lagoon are a total of about 114 coral patches of all sizes that were counted on the aerial photographs. Of these coral patches about two dozen including five at the passes are of comparatively large size, with the rest being mostly small sized coral knolls (Figure 3). Excluding the patches at the passes, the area of coral patches within the lagoon totals 0.3 square miles or 192.8 acres. Most of the large patches lie in the central and west-central parts of the lagoon, i.e., toward the leeward side, and most of the small coral heads lie close to the north and west lagoon fringe. Moreover, the width of the reef itself in the north and north-west half is approximately double the width of the reef in the east and south from where the chief storms and prevailing winds come.

Emory's typewritten report summarizing the physical environment, lists "thirty-five flat islets" along the eastern half of the atoll reef. There are actually only 33 such islets (Figure 3), although the islet of Hare (Figure 23) has three separately named sections denoting the previous existence of three islets which long ago became fused into one. The southern end of present Hare has two sections called Ruawa and Herengaua. The former channel between Ruawa and former Hare was closed by a storm, (apparently the great storm of 1858) and is densely overgrown with coconut and various understory vegetation. The former channel between Ruawa and more recent Herengaua was filled in by wave-driven sand because of the construction of a causeway which still is perceivable, and it, too, is well covered with coconut and pandanus trees, although the trees are small and there is little understory growth.

In size these 33 vegetated land areas (defined as those parts of the raised reef areas that stand above customary high tide level) altogether total only 276.4 acres or about 0.422 square miles. This constitutes only some 1.33 per cent of the total atoll area. In dimensions Hare is the longest, almost 1.29 miles, and has the greatest surface, 79.5 acres. However, it is only from 400-500 feet wide. Werua is the largest from the view of having the central parts the farthest removed from the beach rim, as well as having the next largest area, 41.4 acres. Ringutoru and Torongahai follow in areas with 26.7 and 19.5 acres respectively. Nunakita, Taringa and Matiro are the only others with more than 10 acres of surface. Six islets have less than an acre of surface including Pungupungu with .4 acre and Tiahu with .6 acre. Matukerekere with 1400 sq. ft., hardly 100 ft. long and about 20 feet wide, has only one mature coconut palm and five young coconut plants for vegetation.

The following table lists the areas of the individual islets in succession from north to south (Figure 3).

Table II

Islet name	Area in acres
Torongahai	19.5
Ringutoru	26.7
Rikumanu	.9
Turuaimu	2.0
Pepeio	.7
Nunakita	14.2

Table II, cont'd.

Islet name	Area in acres
Hukuniu	.9
Parakahi	3.1
Werua	41.4
Touhou	9.2
Taringa	12.4
Pungupungu	.4
Matiro	10.3
Matuketuke	1.0
Ramotu	3.5
Sakenge	2.3
Matawhei	.7
Hukuhenua	5.0
Hepepa	2.3
Tipae	1.6
Tetau	7.8
Nikuhatu	2.3
Takairongo	3.9
Tangawaka	7.0
Hare	79.5
Herekoro	3.8
Tirakau	1.8
Tariha	2.2
Tiahu	.6
Tokongo	1.8
Tirakaume	1.3
Pumatahati	6.3
Matukerekere	(1400 sq. ft.)

Total land area	276.4 acres
Total area of encircling reef, including patches at the passes	5,079.4 acres
Total area of coral patches in lagoon ...	192.8 acres
Total of all reef areas	5,272.2 acres
Total lagoon area inside reef	15,201.0 acres or 23.79 sq. miles
Total atoll area.......	31.7 sq. miles

The islets with the greatest breadth transversely across the reef area also are located in the broadest half of the reef. The greatest gaps between islets (i.e. the inter-islet channels) also occur in the northern part of the chain of islets. The closest spacing of islets and the narrowest inter-islet channels occur in the central eastern portion of the chain of islets and face the prevailing east wind. These inter-islet channels run in width from the 55 feet between Matiro and Pungupungu to the 3,250 feet between Turuaimu and Rikumanu. Five such channels are over 1,200 feet wide. Eight are between 500-1000 feet wide. Eleven are between 200-500 feet wide, while the remaining eight are under 200 feet wide.

A chart of depth profiles of the lagoon running east-west and based on the adjusted hydrographic chart is shown in Figure 4. Approximately two-thirds of the lagoon has a depth of less than 180 feet and a little more than a third is under 120 feet. The deepest third runs in a slightly arced zone in the north central part of the lagoon, following generally the contour of the reef. Depths run down to 258 feet in the north central area. Outside of the reef, the drop-off is steepest and most abrupt in the areas near the pass in the south (Figure 2).

THE EVOLUTION OF THE TOPOGRAPHY

The atoll is not far removed from the unstable west Pacific zone of tectonic movements and volcanism. It is not surprising, therefore, that earthquakes are well known to the Kapingamarangi people. Eilers wrote of this in relation to the ancestral cult worship of the people. In addition to the regular worship of the Utamatua, the ancestral deity, on special occasions the Kapinga people used to appeal to him to keep earthquakes from them. Earthquakes occurred from time to time without the inhabitants of the atoll knowing from what direction they came. They believed, however, that earthquakes arose from the sea and that they were sent by Utamatua when someone on the atoll had committed a grave wrong and aroused his resentment. In their prayers to Utamatua, the people asked him to cease his anger and to stop the earthquake. The people were especially frightened when earthquakes happened at night, and in the early morning following such an event they would stream together for prayer. The high priest would wait for the men at the tabu place between the sacred stone and the cult-house. Each man would bring an offering of coconuts to lay before the sacred stone. Following the end of the prayers the coconuts would be eaten.[1]

While these earth movements frightened the Kapinga people, there is no evidence of any significant physical effects brought about by the earthquakes upon the structure or topography of the atoll.

The geological structure and evolution of the atoll is described by the geologist on the team, Edwin D. McKee. However, some personal observations made in the field or from aerial photographs by the present writer are included here.

Figures 5 and 6 drawn from an oblique and a vertical aerial photograph respectively illustrate the various elements in the topography at Kapingamarangi. The reef flat comprises cemented and consolidated limestone bedrock under water at high tide and partly exposed at low tide. Where vegetated islets occur this reef flat extends into the channel area and is covered by sand and coral fragment covered tidal fans with underlying bedrock on the lagoon side. Boulders and larger fragments of consolidated beach or reef rock broken loose by storm waves occur scattered about the reef flat, ranging in size from a few inches to several feet in diameter. They are particularly prevalent in the ocean side flats adjacent to the islets from Werua to Torongahai. The tidal currents running into the lagoon through the inter-islet channels carry with and push before them smaller boulders, coral gravels and sands, and quantities of Foraminifera. These build up tongues of shoal areas into the lagoon, giving a scalloped appearance to the lagoon fringes on the eastern half of the reef where the islets occur. Between these tongues of sand and gravel which kill the live coral they cover, greater depths of water reach close to the lagoon beaches of the islets. Here, tidal movement and accompanying wave action

1. Eilers, op. cit., p. 136.

eroding the shore and working over loose material, together with the work of alongshore currents, bring about an irregular and ragged edge to the coral growth extending into the shallow waters off the lagoon shore of the islets. In the lagoon waters off Touhou an aerial photograph[1] reveals what look like five artificial dredged channels leading from the shallow beach area through the coral growth into deep water (Figure 6). They are 10-20 feet wide and 100-150 feet long. How these originated and what the nature of these apparent channels are were not investigated during the team's stay on the atoll.

Where the inter-islet channels are narrow and especially where causeways have been built between islets, sandbars which form tongues extending from the lagoon sides of islets adjacent to the channels curve across the tidal fans to meet each other as shown in Figure 5. This appears due to the work of along-shore currents in conjunction with obstructed and weakened tidal currents running through the channels. Where the channels are wider or deeper as in the case of Figure 6, the sandbars form separate tongues without curving toward each other.

Cross sections of the islets from oceanside to lagoon shore typically show a sharply rising rampart of coarse coral fragments and gravels that reach a peak elevation of 5-12 feet depending upon the size of the islets and then slope more gradually toward a depression in the ocean-side of the center of the islets. In the smaller islets this may be only a foot or so above high tide. The elevation then rises to a secondary height on the lagoon side of the islet, most often a sandy beach ridge from which there is a moderate slope to the lagoon water and a gentle back slope inland. Figure 7 showing a profile across Taringa and Figure 8 showing a profile across Werua illustrate this, but are complicated by the man-made puraka pits and fields which create artificial depressions and elevations in the central parts of the islets. The elevations in these central parts are formed by the piling up of the material excavated from the puraka pits along the edges of the excavations.

In his report McKee notes various evidences of beach migration involving the destruction as well as the formation of land areas above high tide. His conclusion points to the lagoonward building of the land and the erosional destruction of land on the oceanside. While he presumes that the rate of wearing back of the islets on the seaward side has decreased as the distance from the reef front has increased, he states that it is unknown "whether this aggradational process is as rapid or more rapid than the rate of island destruction on the seaward side". The decreased rate of erosion on the seaward side is counter-balanced in part at least by the retarded sedimentation as island building lagoonward meets continually greater depths of the lagoon, requiring greater amounts of sediment to build up the bottom. On the other hand, the present writer believes that evidences are present supporting the conclusion that island building is proceeding at a faster rate at Kapingamarangi than island destruction, and that the total land area available for vegetation is increasing.

1. ONI Number 47162, vertical aerial photo, scale enlarged from 1:15,000 to 1:5000.

Land destruction.

Time was not available for accurate ground mapping of the dipping rock exposures on the seaward sides of islets that might be considered old beach-rocks. However, the aerial photos taken by a Navy plane in 1954 reveal numerous patches of such exposed beach rock, a number of which also were roughly sketched in from beach reconnaissance during the team's stay in 1954. It may be presumed that between the seaward edge of these patches of beach rock and the present beach line, vegetated land once existed that now has been eroded away, leaving the remnants of the former beachrock. The largest remnants or patches of beachrock occur on the seaward sides of Torongahai, Ringutoru, and Nunakita in the north, and on the seaward sides of the numerous small islets between Pungupungu and the northern end of Hare. Significantly, little of it is found on the seaward side of the mile-long islet of Hare immediately to the south. Relatively little is found on the seaward side of Werua. Two inferences might be noted from this. One is that small islets erode away proportionately faster than the larger ones. Actually, the ratio of the amount of erosion to the seaward length of shore-line is higher for the smaller islets than for the larger ones, and hence the smaller islets can be said to be eroding away faster.

According to Rikaneti, the present small islet of Matukerekere which has a surface above high tide of only about .03 acre, was about the size of present Pepeio, 0.7 acre, prior to the storm of 1858 which washed off all the vegetation and most of the land surface. The second inference is that while increased distance from the reef edge for a particular beach may de-crease the rate of erosion for this beach, orientation and size are more important erosional factors than distance from the reef as such. Thus, the seaward edge of Hare, which shows little beach rock exposure from erosion and also is situated on a narrow part of the reef, is close to the reef edge in contrast to the seaward edges of Nunakita, Ringutoru and Torongahai which have large areas of beach rock exposed by erosion, but are situated on the broadest part of the reef and have seaward beaches much farther from the reef edge than in the case of Hare. Moreover, since the prevalent storm winds and waves sweep in from the east and southeast, the waves must cross the reef in the north diagonally and hence pass over a long stretch of reef flat before hitting the beaches of the northern islets. Yet the erosive force is such as to have apparently caused the greatest extent of land destruc-tion precisely in the seaward parts of these northern islets.

The rate of erosion is hard to estimate and differs in different parts of the atoll and on different sides of the islets, as well as depending upon the character and occurrence of the storm waves. Erosion appears more severe on the lagoon side of the southern section of Hare than on the sea-ward side. At a part of the lagoon shore 1000 feet from the southern end several living coconut trees stand on tongues of land 3-5 feet wide protrud-ing ten or fifteen feet lagoonward from the main shore-line, showing that long after maturity of the trees, the shoreline here had receded this dis-tance. Much of this may have occurred during a single storm, since the

beach and adjacent land area here is composed mainly of sand. This may have been the result of a 1947 storm which destroyed a large part of what remained of the tiny islet of Matukerekere near the southern pass area. (Discussion of the storms of 1858 and 1947 follows in the next section on: The climate and weather of Kapingamarangi.)

Across the lagoon to the north, the seaward side of Torongahai has numerous fallen coconut logs and stumps on the beach, while many of the live Guettarda, Scaevola and Messerschmidia of five to 12 inch diameter trunks have sprawling roots exposed reaching up to ten feet out from the present beach-line. This shows that at least this much erosion has occurred during the mature life of the trees. Such evidences give only vague notions of the rate of beach recession. It is naturally much faster where the shore is formed of unconsolidated cobbles and gravels than where cemented rock forms the shoreline. Thus, in the case of Rikumanu, the tiny islet near Ringutoru, the owner, Materewei, stated that he had not noted any significant reduction of the land surface during his lifetime. Yet the shorefront was very jagged from erosion and at the lagoon end was undercut some six or seven feet, leaving an overhanging rock platform three or four feet thick on which, strangely, bearing coconut trees continued to grow.

Lateral erosion in the inter-islet channel sides of islets also may be of great severity. The east-west elongated shapes of the islets between Matiro and Hare appear to be the result of such lateral erosion from the rush of storm and tidal water through the channels. Ringutoru's incurving eastern shoreline exhibits severe erosion and undercutting which in the course of time may cut the islet into two segments near the middle. The elevated ridge of reef rock between Hukuniu and Parakahi may represent the remnant of a land connection rising above water between the two islets.

Land building.

Land building occurs naturally and also is aided and induced by man at Kapingamarangi. Here we have some definite indications of the rate of building or land enlargement. For instance, on the southwest lagoon beach of Torongahai, Scaevola covers a zone of some 20 feet and represents three stages of growth. The inner part of the zone had Scaevola trees 10 feet or over in height. A middle band of Scaevola was generally around 6 feet high. A third band was composed of seedlings of from a few inches to a foot or two in height. The latter were growing on open beach sand above the usual high tide line.

Torongahai and Ringutoru both have advanced lagoonward considerably during the last 40 years, according to Chief Tuiai, and more land has been added here than has been eroded away on the seaward or channel sides. Tuiai tells of an old tree near the lagoon on Ringutoru whose trunk was near the waterline when Tuiai was a boy. Since then sand has filled in more than 40 feet lagoonward and this new land has become vegetated. Tuiai stated that men used to climb a coconut tree next to the old tree and jump or dive into deep water of the lagoon from the top of the coconut tree.

Since Tuiai was about 52 years old in 1954, his recollection probably refers to a boyhood about 40 years or so ago. This would indicate a rate of beach building lagoonward of about a foot per year on the average. Such rates of beach building do not occur on all lagoon beaches, of course, but there appears to be a noticeable rate of lagoonward building on most of the islets. While impressions of dimensions among the inhabitants are not to be trusted as reliable, they do provide some worthwhile indications of change. Tuiai stated that during his boyhood the islet of Turuaimu was about the size of present Pepeio adjacent to it. The areas of the two islets as mapped in 1954 were 2 acres and 0.7 acres respectively, so that if Tuiai's impressions were taken at their face value, Turuaimu has doubled in size during the 40-45 year's period since his boyhood.

Support for this estimate of the rate of land growth is provided by the speed with which land has been created by man-induced means. The Kapinga people long ago learned that they could build up land areas by piling up walls or mounds of loose coral blocks on the reef and then let the waves and tidal currents accumulate gravels and sands in the leeward sides of such walls or mounds. The chief residential islet of Touhou which now has a surface of 9.2 acres was thus formed by the first inhabitants of the atoll, according to traditional history. Utamatua, who purportedly discovered Kapingamarangi while searching for his despondent wife who had cast herself adrift on the ocean, is said to have chosen the site of Touhou islet for his band of followers. Since he is supposed to have found prior inhabitants at the atoll, he apparently decided to create new land for his group, and he built up Touhou from a mere ledge of rock, according to the account given to Emory. The same account mentions the existence of Turuaimu before Touhou was built, however, so that it would seem that Turuaimu has been building up rapidly only during the last half century since Tuiai said that it had doubled in size during this period.[1] It is probable, however, that the islet may have been enlarged and then reduced several times during its existence, since it is built mainly of gravel and sand.

In addition to Touhou, two other islets are said to have been built by the Kapingamarangi people. One is Pepeio, built only a few decades ago. Meterewei, who was employed by the 1954 expedition, said that his father built up a wall of coral rock on the ocean side of a patch of sand that had risen above high tide. Sprouting coconuts were planted on the coral wall as it was built up. He said that the coconut trees were planted 24 years ago and that over 10 of the larger trees now were producing nuts. (On the other hand, Rikaneti said the wall was started in 1919). Scaevola and Guettarda both were planted there to hold down and bind the sand, rock and rubble. As Pepeio grew larger, more coconut trees were planted. Today, Pepeio has a vegetated surface of 0.7 acres.

Tipae, an islet now having 1.6 acres of vegetated surface, also was man-induced. The coral block wall or mound on the seaward third of Tipae was still clearly in evidence during 1954 and, in fact, the piled up boulders were still loose underfoot when Niering and the present writer walked over them. No date was ascertained for the initiation of the wall.

1. See Emory's section on "Traditional History".

The German South Seas Scientific Expedition of 1910 stated that Kapingamarangi had 31 islets with soil and vegetation and three sand islets. It is probable that at this time, the islet of Herengaua was still separated by a channel from the southern end of Hare. Matukerekere then had not even the one mature coconut tree that now stands guard on the patch of sand and gravel, so that the three "sand islets" no doubt comprised this islet and Pepeio and Tipae.

Another method of creating new land is to build causeways across the channels to connect two islets. This results in the gradual filling in of the channel with sand and gravels on both sides of the causeway. Owing to the closing of former channels, the two former separate islets of Ruawa and Herengaua have been fused with Hare into the present Hare. A storm choked the channel between Hare and Ruawa (apparently the great storm of 1858), while a man-made causeway brought the filling in of the second channel between Ruawa and Herengaua. Field mapping of the former channel shores and of the beach lines of the former islets indicated that the filling in of the channel area between Hare and Ruawa has resulted in the addition of 4.7 acres of land surface now vegetated. The mapping also showed the extent of former Herengaua to be approximately 2.18 acres and of the filled in area of the channel between Ruawa and Herengaua plus the lagoonward extension of Herengaua to amount to 2.6 acres of surface now mostly vegetated.

The causeway between Ruawa and Herengaua is clearly visible on the lagoonward side where part of the old channel forms a depression. The recency of this filling in of now coconut-overgrown land is indicated by the fact that an aerial photograph of World War II (probably dated in early 1943) (ONI No. 47159) shows Herengaua connected by only a narrow strip of sandy land to the Ruawa sector of Hare, with what appears to be seedling vegetation of some pioneer species on central parts of this connecting land.

Although no definitive statement of the rate of land surface increase or decrease can be made, nevertheless, it appears most probable from the evidence pointed out that the total land surface that can support vegetation is increasing in area at a relatively rapid rate and that effort on the part of the inhabitants can further increase the total habitable and productive land.

THE CLIMATE OF KAPINGAMARANGI

The climate of Kapingamarangi remains a matter of estimate derived from weather station data at Ponape and Truk, scattered data from passing ships, some general notes taken by Emory during his several months stay from July 15 to October 16, 1947, and from the seven weeks of systematic meteorological data recording during July and August by the present writer (Appendices I and II). The Sailing Directions for the Pacific Islands, Vol. 1, 1952, H.O. 165A, p. 267-268, give a description of the climate for Kapingamarangi the source of which is not indicated, and there are some doubts of its validity owing to conflicting data from other sources. For lack of more reliable information, however, this description is included below.

The Eastern Carolines lie in the zone of the northeast trade winds which ordinarily prevail from November to April, with considerable variation from year to year. The strongest winds occur during the height of the northeast trades.[1] According to the Sailing Directions, in Kapingamarangi northeast and east winds prevail from December through April, with a frequency of 68% and an average velocity of 11 knots. In May and June variable winds prevail, with an average velocity of 7 knots and with calms occurring about 11 per cent of the time. From July through September winds from the southeast quadrant occur 55% of the time, with an average velocity of 8 knots, and with calms 5% of the time. On the other hand, the directions of winds observed by Emory during the period July to mid-October 1947 and those recorded by the present writer during July and August, 1954, were almost always from the east with the exception of winds during a few scattered days.

In October and November, the Sailing Directions indicate, winds average 7 knots from varying directions, with southeast being most frequent or 24%. From October through January, westerly winds of 15 knots average velocity are experienced 10% of the time. These accompany the storms occurring in these months. Emory states that beginning in November and for several months thereafter, the winds blow rather heavily from the south and rains are heavy.

According to the Sailing Directions, rainfall is heaviest in May and June and again in October and November, during the passages of the doldrum belt, when the average is about 12 inches per month. Rainfall is relatively light from February through April, and from July through September, averaging about 7 inches per month. In December and January, rainfall averages about 9 inches monthly, much of this occurring during stormy weather. From these averages, it would appear that the average annual rainfall is 108 inches. By contrast, Emory quotes Janis Report 104, vol. V, p. 27-30, to the effect that the average annual rainfall is 78 inches, with the greatest monthly rainfall, 8-12 inches, occurring in December and January, and the least, 1 to 2.5 inches, occurring during April, May, September

1. U. S. Navy, Office of Naval Operations, Civil Affairs Handbook, East Caroline Islands, 21 February 1944, p. 6.

and October.

From his own observations, Emory says that in July and August 1947, "rain squalls quickly filled all water barrels, but during September and October in both 1947 and 1950 almost no rain fell, bringing on a shortage of fresh water for drinking, bathing and washing clothes". From the present writer's own records, in seven weeks of July and August 1954, the rain gauge from which daily recordings were made showed only 4 inches of rainfall, while weekly recordings at three scattered points on the atoll indicated 3.39, 3.93 and 1.57 inches respectively. This is in contrast to the 7 inch monthly averages for this period recorded in the Sailing Directions. From Emory's and the present writer's observations, September and October in 1947 and 1950, and July and August in 1954, appear to be extremely dry periods if the averages given in the Sailing Directions are "normal" or derived from many years of observation. The latter situation could only be possible if the Navy has obtained Japanese weather data collected during the period before the Americans destroyed the Japanese weather station on Kapingamarangi in World War II. A concrete tower for meteorological instruments was constructed on the south end of Nunakita Islet in the northern part of the atoll by the Japanese, but was bombed and wrecked by American airplanes.

It is probable that rainfall is highly erratic from year to year as well as during the course of a year. Storms are of small diameters in this part of the ocean and are as likely to miss as to pass over a particular patch of the ocean occupied by a low coral island or atoll. The Sailing Directions state that "Typhoons never occur. Squalls and thunderstorms constitute the major weather hazard. These storms, normally from 20-25 miles in diameter, are accompanied by winds averaging from 15-25 knots, with occasional gusts up to 40-50 knots. Thunderstorms occur on an average of two days per month from May through November, and once a month for the rest of the year." During the Kapingamarangi Scientific Team's stay on the atoll in 1954 there was only one extended period of overcast skies. This occurred at the end of July when rain from overcast skies began at 8:30 P.M. and continued during part of the night. Overcast skies continued through the next day and the following evening. Rainfall during this period at the Touhou Islet station amounted to only 0.74 inches, however.

An interview with Rikaneti, the community secretary of Kapingamarangi, yielded the following information concerning recorded storms of significance affecting the atoll. The first account in the records (handed down by word of mouth and subsequently written down) indicates a very severe storm in 1858 that destroyed much of the tiny islet of Matukerekere in the south part of the atoll. A man was killed on one of the larger islets by a falling breadfruit tree. In 1886 during the rule of the Ariki (priest) Tahikimau, a storm caused much damage to breadfruit and coconut trees. In 1896 a tidal wave damaged the lagoon beach from Werua Islet to Ringutoru Islet, but did relatively little damage to coconut and breadfruit trees. In 1920 a thunderstorm with heavy rains did some damage to coconut trees. In 1937 when the Japanese administrator Sato was at Kapingamarangi, a storm blew down five breadfruit trees. The date of the last great storm

is given by Emory as occurring in November 1947, while Rikaneti said it occurred in 1948. According to the latter, this was one of the worst wind storms that have visited Kapingamarangi. The account of damage differs. Emory was informed by Hetata that 201 bearing breadfruit trees were blown over. Rikaneti, however, listed 67 breadfruit trees, 10 coconut trees and 30 houses as having been blown over, while six puraka fields or pits (mostly on Ringutoru) were damaged by salt water.

The worst storms apparently come from the southeast, or at least the effects are most serious when they come from this direction because the water piles up in the lagoon through the passes and open reefs in the south and sweep across the lagoon, causing severe alongshore erosion on the lagoon side of the islets on the eastern rim as well as damaging the northern islets through sea water innundation. The Sailing Directions state that thunderstorms occur on an average of two days per month from May through November, and once a month for the rest of the year. During the stay of the scientific team in 1954 no such storms were noted.

Extended droughts occur at long intervals when famine may visit the atoll. Emory has noted two, one in 1890 and another that lasted from 1916 to 1918. During the latter 80-90 people died directly or indirectly as a result of famine. It has already been pointed out that Emory recorded almost rainless Septembers and Octobers both in 1947 and 1950. The distribution of rainy days during the scientific team's stay in 1954 was as follows. From June 25 to July 17 there were 11 days out of 22 without rain, half the days. A dry spell of 10 days followed, beginning July 18 and ending July 28 when 0.24 inches of rain fell. Between July 27 and August 22 there were 13 days of rain out of 26, again about half the days, with a seven day period of drought from August 10 through August 15. Clouds observed were mostly of the cumulus humilis variety and seldom had enough size, altitude and turbulence to produce rain.

The average maximum temperature over the period recorded during the 1954 visit was 89.1° F. Average minimum temperature over the period was 82.5° F. Absolute maximum was 94° F. while absolute minimum dropped to 74° F. The humidity normally fluctuated inversely in relation to temperature change as would be expected. Maximum temperature readings generally coincided with lowest humidity readings on the hygro-thermograph charts. Average daily maximum humidity reached 83.8 per cent, generally during the period from midnight to sunrise. During less than a quarter of the days recorded, the humidity reached as high as over 90 per cent. The average daily humidity dropped to 57.4 per cent and reached the low point between noon and 4 P.M. Three-fifths of the time recorded, this occurred between 2 and 4 P.M. About a quarter of the time, the minimum humidity dropped to 55 per cent or below. The lowest humidity reading reached 48 per cent on August 14 when the highest temperature reading of 94° F. occurred at 2 P.M.

An anomally from the usual pattern occurred on July 31 when temperatures remained fairly even from 11 A.M. and 7:30 P.M. while humidity dropped. On the following day, August 1, temperatures dropped 2 degrees from 5 A.M. to 7 P.M. with a greater rate of rise in humidity. This period marked the occurrence of the only extended general atmospheric disturbance when overcast skies lingered for two days.

OCEAN CURRENTS AND LAGOON CURRENTS AND TIDES

The Sailing Directions state that the sea and swell are from the northeast from December through April, with heights of 2-4 feet. From May through November the seas and swells come mostly from the southeast, with heights of 2-3 feet. From October through January seas and swells coming from the west average 5-6 feet in height for about 10 per cent of the time. Local squalls and thunderstorms raise choppy and confused seas. That the ocean currents which run past the atoll are very strong is attested to by the German scientific expedition that stopped at Kapingamarangi in January 1910.[1] The course of the expedition ship "Peiho" was driven 15 sea miles to the east, and Eilers speculates that it possibly was because of this current that the Captains Symington and Montraval in 1864 and 1853 respectively, gave up the idea of visiting the atoll. This also may have been in part the reason why information about Kapingamarangi remained so long uncertain and so scarce in spite of the fact, according to Emory, that this was the first atoll occupied by Polynesians that was sighted by Europeans. Captain Blanc of the Steamship Roque on which the present writer traveled to Kapingamarangi informed the writer that in traveling from Nukuoro, he set his course during the August trip for a point about 18 miles to the east of Kapingamarangi to compensate for prevailing westward drift, but that there had been a change in the direction of the drift to a current setting in the opposite direction. As a result he found himself 32 miles off course to the east, since the change had reinforced his compensation by an additional 16 miles. This points to a certain erratic character in the ocean currents here.

On the other hand, the converted Japanese fishing boat named the "Lucky" that the Kapinga people use for trading trips between Ponape and the atoll, started south about the same time as the Roque but drifted far off course westward with the current and wandered about for some 49 days, managing to make a westward and then northward circuit through Puluwat, Truk and back eastward to Ponape, having lost hope of hitting Kapingamarangi. The Sailing Directions have only a brief reference to these currents. It says that in June of 1926, a weak westerly current was experienced between Kapingamarangi and the Namoluk Islands northwest of Nukuoro.

Tidal currents occur at the main passes into the atoll lagoon and the maximum velocity at these passes, according to the Sailing Directions, may reach 5 knots. These currents occur in all the inter-islet channels, of course, running most rapidly with the incoming tide. The maximum tidal fluctuation during the recorded period in July and August was about four feet between high and low tides.

The graph of a tide gauge, which was installed by the expedition at the end of the pier in the lagoon off Touhou village, shows an interesting

1. Eilers, op. cit., p. 11-13.

rhythm of rises and falls. During the 24 hours there generally are two peaks and two troughs, but at 15 day intervals the two peaks merge into one. The two peaks are not of equal height, although they gradually approach this state as they reverse their relative positions of maximum heights near the end of the 15 day cycle.

The graphs for the period from noon of July 11 to noon of July 25 serve to illustrate the evolution of the various stages (Figure 9). A low low-tide occurs at noon on July 11, rising half a foot to a low high-tide peak at 4 P.M. Thereafter, there is a slight drop of less than 1/10th of a foot to a high low-tide trough at about 5:30 P.M. There then is a sharp rise of 1.5 feet to a high high-tide peak at 1 A.M. From this the tide drops steadily 2.4 feet to the low low-tide trough at about noon the next day, July 12. This completes the 24 hour cycle.

However, with each succeeding day, both peaks grow progressively higher, while both troughs drop to successively lower levels until July 16. At this date the maximum difference of almost exactly 4 feet between high high-tide and low low-tide is reached. From this point on to July 21, the level of high high-tide decreases, while the level of the low low-tide, the high low-tide, and the low high-tide all are increasing.

On July 21 the levels of the two high tides between successive noons are approximately equal, and the difference between these two high peaks and the high low-tide trough between them is only 1.3 feet, and that between the former high high-tide and the following low low-tide is only 1.9 feet.

From this point on the two peaks change their relative levels. The former high high-tide level now is surpassed by the level of the former low high-tide which now becomes the high high-tide. In three days the former high high-tide peak has been leveled and disappears, merging into a single high tide in the 24 hours from noon of July 24 to noon of July 25.

July 25 is the beginning of a new cycle of development of the double peak and double troughs for tidal fluctuation within a 24-hour period. This second cycle ends on August 9 when the 24 hours between noon of August 9 and noon of August 10 again brings a single high tide. Thus, each 15 days sees the completion of one cycle on the graphs recorded during the following four periods:

June 27 to July 11
July 11 to July 25
July 25 to August 9
August 9 to August 22.

The coincidence of the cycle with the lunar stages is obvious, of course.

The general and specific ecological conditions on the vegetated land areas of Kapingamarangi have been studied by the land ecologist of the team, William Niering, and the discussion of these aspects is largely left to him. A few comments on the vegetational pattern are included here, however, as an introduction to the economic contribution of the vegetated land areas.

Emory made a list of names of plants occurring at Kapingamarangi and collected by Ray Fosberg and Edward Hosaka in 1946. This is given in his report on The People of Kapingamarangi. William Niering collected more extensively in 1954 and describes the plants as he found them. Coconut is universally present on the islets and is the most conspicuous plant. It grows up to the beach edge in either sand or porous coral rock. It is of first importance in the list of economic plants and as a food source, while its fronds are used in roof thatching. Second in economic importance among the tree species is the breadfruit tree, the largest and tallest of the trees on the atoll. It is found only on the larger islets and generally in the middle and higher parts of these islets, because of its sensitivity to salt spray and to saline ground water. However, on Touhou it grows very near the water's edge on the lagoon side, and the edge of its leaf canopy virtually overlaps the high tide line at places. On most of the islets where they occur, however, they tend to be restricted to areas a hundred feet or more from the water's edge. This is in accord with Stone's findings on Arno about which he wrote: "Generally the tree reaches maximum development in the sheltered interior of wider islands but large open-grown trees are found in settled areas and occasionally very close to the beach."[1]

The larger breadfruit trees may rise to 120 feet high and grow to five or six feet in diameter breast high from the ground. While perhaps not as important in the diet as puraka (Cyrtosperma chamissonis), breadfruit is one of the staples together with coconut, puraka and fish. The trunks of the larger trees are used for making the dugout canoes that form the sole means of transportation over the water, although a single whaleboat was a part of the community property on the atoll.

Another important tree is the Pandanus, whose leaves are used in the making of mats and baskets and whose coarse-fibered fruit is chewed to extract a sweet and tasty juice or is cooked and mashed into cakes which supply a starchy, fibrous food. The orange colored segments undoubtedly form an important source of Vitamin A in the diet. The occurrence of Pandanus is sporadic among the islets. On parts of some of the larger islets it may be thickly planted, as in the central puraka field borders on Werua. Typical locations for it are on the ridges of debris dug out of puraka pits, but it grows anywhere, although subject to salt spray damage on the leaves if the plant stands at the beach edge.

1. Stone, Earl L., The Soils and Agriculture of Arno Atoll, Marshall Islands, II Agriculture, p. 16.

Two species of trees are light tolerant and relatively tolerant to salt spray and saline ground conditions. For these reasons they commonly form an outer fringe along the beach ramparts, particularly on the seaward and channel fringes and generally as an understory of the coconut tree. These are Guettarda speciosa known by the native name of pua, and Scaevola frutescens, known as nau. Almost all islets except Matukerekere and residential Touhou appear to have these. Small poles from the former are cut to be used in the lattice walls of the houses. Guettarda is an important understory species especially on smaller islets. Scaevola and Guettarda appear useful primarily as beach binders to retard erosion. Messerschmidia argentea, known as tokotokong, also is a light tolerant tree prominent on the seaward or channel sides of a number of islets, although mainly confined to the larger islets of Torongahai and Ringutoru in the north part of the reef.

Occurring almost always on the lagoonside of the various islets on which it grows is Calophyllum inophyllum, called hetau by the Kapinga people. The trunks of these trees grow to two or three feet in diameter on the atoll, and they are used for the making of coconut graters, boxes and bowls, and for adze handles.

In the interior of the islets and growing as understory vegetation is Premna obtusifolia locally known as woroworo, whose trunks grow to a maximum diameter of about 6-7 inches and are used for making canoe paddles because of its tough, light wood. Another such understory tree of small size is the Hibiscus tiliaceus, locally called hau. Vertically rising branches from almost horizontally growing trunks of this tree provide straight, tall sail poles for the canoes. The raised banks of puraka pits are common locations for the planting of such trees. A small understory tree used for roof rafters is Morinda citrifolia, locally called nonu, and it grows on most of the islets. A small shrub that forms dense thickets at places on some islets is the forsythia-like Clerodendrum inerme, here called hia. Trees of less importance such as Barringtonia asiatica (rakau-iha), Pisonia grandis (puke), Hernandia sonora (pingipingi), Ochrosia oppositifolia (kaniu), and on Pumatahati numerous Cordia subcordata (rakau me) have been noted by Niering.

Among the food plants other than fruit-bearing woody trees, the foremost is Cyrtosperma chamissonis, locally called puraka. According to Emory, its ability to withstand drought has caused it to supplant taro to a very large extent in the pits. Arrowroot is a small understory tuberous-rooted plant that provides a starchy food and is found scattered about the interior of some of the islets. Banana plants are not very numerous because of competition for space with other plants, but they produce good fruit considered a luxury food. A few papaya trees produce rather small fruits considered of little value as food. Nukuoro atoll farther north produces some limes, but although some citrus plants were observed on Kapingamarangi by Niering, no fruit was seen.

A number of weed pests occur. In sections of the beach fringes on Torongahai and Ringutoru a string-like creeper vine (Cassytha filiformis)

formed tangled masses choking the Scaevola and Messerschmidia on which it climbed. A daisy-like weed (Wedelia biflora) grew in great profusion on Hare in sunny open areas. Two leafy creeping vines also were found. One of these (Vigna marina) grew over smaller trees and killed their foliage. The other is a morning glory (Ipomoea tuba) which forms a ground cover and has some value as pig feed. On all the larger islets such as Torongahai, Ringutoru, Werua and Hare there grew several types of ferns, of which Asplenium nidus is most widespread, growing on old coconut stumps and on the trunks of older coconut trees as well as on the ground. On Torongahai and Ringutoru especially, the Nephrolepis hirsutula fern formed a luxuriant cover over much of the ground in the interior of the islet.

Data on vegetation character and distribution were gathered and plotted directly on field maps by Niering and the present writer. It was quickly obvious to them that the high degree of manipulation of the vegetation by man obscured the natural vegetation succession and that it was very difficult to interpret the natural ecology and environment from the apparent patterns. This was especially true of the understory vegetation patterns, which depended largely upon the landowner's activity and whims. On the same islet a patch of well-cleaned and weeded ground would occur next to densely overgrown land.

Generalizations of the vegetation pattern for certain major categories, however, may be made. There is a concentric zoning of certain types of plants: On the larger islets, puraka occur in the central portions where pits have been dug down to the fresh water lens. On the peripheral raised banks of these pits breadfruit trees appear to be most abundant and flourishing with Pandanus as a prevalent understory (Figures 8 and 15). A zone where coconut and breadfruit trees occur in mixed stands then surrounds this, with miscellaneous understory vegetation such as Hibiscus, Premna, Morinda, Pandanus and Guettarda, and with a ground cover of weeds, ferns and grass. This zone in turn is followed by a zone where coconut is dominant, but with similar understory vegetation, which extends out to the margins of the land. A narrow zone beyond the coconut zone may intervene between the rubble rampart and the water's edge especially on the seaward and channel margins where Guettarda and Scaevola and sometimes Messerschmidia accept conditions unfavorable to tree forms other than the coconut. Since coconut trees grow all the way to the beach edge, these species may form understories of the coconut in a narrow beach fringe.

On the accretive sand beaches extending lagoonward, Scaevola and certain beach grasses form a pioneer vegetation which may be followed by Guettarda, coconut and Pandanus. On the smallest islets virtually nothing except coconut and Guettarda and Scaevola may grow.

In conclusion, it may be noted that of 98 vascular plants observed by Niering, 38 are classed by him as indigenous, 56 as introduced and 4 as of drift origin as seedlings only. The term "indigenous" appears to distinguish plants present during pre-European times some of which probably also were introduced by man. The term "introduced" indicates that plants were

brought in through the agency of man or of man's activities. From the above list, it is obvious that the pre-European "indigenous" vegetation was much more limited than the present-day vegetation on Kapingamarangi. Some of the "introductions" include the highly important Cyrtosperma or puraka and the taro-like Alocasia macrorrhiza, the banana, the arrowroot and some varieties of breadfruit. The "indigenous" breadfruit itself was introduced, according to Eilers,[1] prior to the coming of the white man, purportedly from Woleai Atoll in the western Caroline Islands. This early lack of breadfruit trees may have been the cause of the origin of the priestly control over this valuable tree and their fruit and of the dugout canoes made from the tree.

1. Eilers, op. cit., p. 150.

Emory states that the only animal on the atoll until foreign vessels introduced dogs, cats, chickens, ducks and pigs was the small brown Polynesian rat. Dogs were present on the atoll in 1910, but were exterminated presumably during World War II or immediately after because they had no function and killed the cats which served a function. Information is not available as to whether the dogs were eaten as on other Micronesian islands. Cats were introduced after 1910 and have become numerous since the extermination of the dogs. On the residential islets of Werua and Touhou, they have killed off practically all the rats, although on the larger outlying islets, especially on Hare, rats are found around the houses.

A count of the pig and chicken population by an animal husbandry specialist with the U. S. Commercial Company in August 1946 and reported by Emory gave a total of 288 pigs and 946 chickens on Kapingamarangi or more than a pig for each two persons and almost two chickens per person. Chickens run wild and ownership is identified by the toes cut off at various joints. Chickens are kept only on the larger islets. Pigs are small, black, inbred specimens for the most part and are kept tethered by a foot to a tree with rope or in pens. Because of lack of feed materials and the relatively high value of copra, pigs are poorly fed. An insufficient amount of water fed them also contributes to a scrawny animal. Pigs were less numerous in 1954 than the reported number in 1946. However, both chicken and pigs provide luxury foods for feast occasions. Three or four ducks were observed on Ringutoru Islet, but they appeared to be more curiosities than economic animals.

The only land crab that is eaten appears to be the coconut crab which grows to large size and is caught around the base of breadfruit trees where it hides among the roots and prowls about the adjacent taro fields. The other forms of land crabs and the hermit crabs serve useful functions as scavengers and as aerators of the soil through their habit of tunneling into the ground and churning up the organic material in the soil. Several varieties of small lizards, i.e., two species of skink and two of gecko, occur which feed upon flies and mosquitoes. Flies sometimes are a nuisance, but mosquitoes are numerous only on some of the outlying islets, especially Nunakita where pools of water collected in remnants of concrete structures erected by the Japanese and destroyed during World War II, form breeding places. Because of the few open pools where mosquitoes may breed, it would be a relatively easy thing to wipe out the mosquito on the atoll. However, on the residential islet of Touhou, they were virtually non-existent, so that no mosquito net was required by the expedition members. Flies were relatively numerous only on the leeward or lagoon side of Touhou, because the usually brisk breeze on the seaward half kept them away from this side.

Emory mentions that cockroaches had become a nuisance. This was not substantiated by the experience of the expedition in 1954 when few were noticed.

The noddy and white-capped tern, the frigate bird, and the starling are the most numerous and commonly seen birds on the atoll. On Werua, Ringutoru, and Torongahai the white-capped terns seemed especially prevalent. They nest thickly on some breadfruit trees, and their excreta dropping on the limbs have killed many of the branches on such trees. On Touhou birds, except starlings, are less numerous because of the presence of people. Frigate birds are largely localized in the southernmost uninhabited islets of Pumatahati and Tirakaume which are the only islets where they roost in large numbers. Their sorties in circling mass flights over various parts of the lagoon inform the fishermen of the presence of schools of fish. Occasional noddies, white terns, reef herons and cuckoo may be seen about the islets. Some of the frigate birds are kept as pets.

In the study of the economic vegetation of Kapingamarangi, the limits of breadfruit tree growing areas were mapped roughly on the islets where these trees occurred. Native assistants were trained to do this on the field maps. The method used was to pace parallel to the beach edge and at every hundred feet to pace inward at right angles to the beach until the edge of the breadfruit canopy was reached. Thus the approximate bounds of the breadfruit zones were demarcated. Twelve of the larger islets grew breadfruit trees, although a few grew only one or two trees. The food producing land could be divided into four general types of vegetation zones: puraka fields or pits, a zone of coconut dominance, a zone of mixed breadfruit and coconut trees with both having about equal importance, and a zone where breadfruit trees are dominant. The smaller islets have neither puraka pits nor breadfruit, because the fresh water lens does not exist or is not significant in them, while salt water spray also inhibits their growth. The designation of a breadfruit dominant zone was made only in the two residential islets of Touhou and Werua where special conditions prevail. In the case of Werua, a large area in the center and adjacent to the puraka pits and fields was covered mainly with a breadfruit tree canopy, although a scattered sprinkling of coconut trees were to be found among them occupying an insignificant amount of space. In Touhou, the breadfruit tree crowns nearly reach over the lagoon beach in places and intermingle with Pandanus trees in the central portions. The density of the canopy is not great, however, because of the numerous thatched houses occupying the space, while coconut trees also are few and are confined mainly to the outer fringe.

To get a basis for estimating tree density for the different types, counts of all the trees of certain species were made in selected and representative plots measured off by tape. Thus, on Werua, in the coconut dominant zone, four separate plots each 52 by 52 feet square were measured off and all the trees in them counted. Two such squares also were measured and the tree count made on different parts of Parakahi Islet. On Hukuniu and Matawhei, all the coconut trees on the islets were counted. Distances between the bases of the coconut trees were measured to get the general distribution pattern and the density, while tree heights were estimated. In the mixed breadfruit and coconut zone on Werua, three representative square plots each 104 by 104 feet were measured and counts made of the number of coconut trees and the number of breadfruit trees. The tree diameter was measured for each breadfruit tree. The same thing was done for two representative square plots 104 by 104 feet in the zone of breadfruit dominance. These tree counts are listed in the following lists:

Coconut dominant zone
(2,704 sq. ft. plots)

Plot number	Bearing coconut	Immature coconut	Mature Pandanus	Young Pandanus
1	8	2	14	5
2	5	-	9	1
3	4	-	19	2
4	9	-	7	5

Mixed breadfruit-coconut zone
(10,816 sq. ft. plots)

Plot number	Breadfruit	Bearing coconut	Immature coconut	Mature Pandanus	Young Pandanus
1	5	16	2	25	14
2	5	11	-	18	8
3	4	8	-	8	-

Breadfruit dominant zone
(10,816 sq. ft. plots)

Plot number	Breadfruit	Bearing coconut	Immature coconut	Mature Pandanus	Young Pandanus
1	11	1	-	125	27
2	13	13	6	130	54

The count on Hukuniu indicated a stand of 85 coconut trees or a per acre stand of 94.4 trees, while the per acre stand on Parakahi was 148 trees. On the basis of the average of the Werua counts in the coconut dominant zone which corresponds to the coconut dominant area on Hukuniu and Parakahi, the per acre stand on Werua was 104.6. If these three figures for the coconut dominant zones are averaged, the per acre number of trees in this zone for all the islets may be estimated at 115.7. For lack of additional sample counts, the counts for breadfruit trees and coconut trees in the other other vegetation zones on Werua may be taken as representative of the per unit numbers of trees in the major vegetation zones for the various islets. The tree counts, translated into per acre number in the following table were used in calculating the relevant figures for the different islets in Table III:

Zone	Number of Coconut trees	Number of Breadfruit trees
Coconut dominant zone	115.7	---
Mixed breadfruit-coconut zone	47.15	18.9
Breadfruit dominant zone	28.2	50.37

Average distances between the bases of coconut trees and the estimated tree heights were as follows:

Islet	Average distance	Number of measurements made	Tree heights estimated
Hukuniu	21.3	14	42-60
Parakahi	16.1	13	60-85
Werua Coconut zone	20.8	25	80-100
Werua mixed breadfruit-coconut zone	26.5	24	80-100
Average for all areas	20.9	--	--

In the mixed breadfruit-coconut zone of Werua, on the basis of the sample counts, the per acre number of breadfruit trees of various diameters as well as the actual number of each diameter within the 32,448 square feet in the three sample plots were as follows:

Diameter of tree in inches	Actual number of trees in 32,448 sq. ft. sampled	Number of trees on per acre basis
6-8	4	5.4
9-10	3	4.0
11-14	3	4.0
24-26	2	2.7
36-39	2	2.7

In the breadfruit dominant zone, the per acre number of breadfruit trees of various diameters as well as the actual number of each diameter in two sample plots totalling 21,632 square feet were as follows:

Diameter of tree in inches	Actual number of trees in 21,632 sq. ft. sampled	Number of trees on per acre basis
1	1	2.0
4	2	4.0
6-8	3	6.5
13-14	3	6.5
16-17	3	6.5
24-27	3	6.5
29-31	4	8.7
35-38	4	8.7
61.5	1	2.0

Counts for the *Pandanus* tree in each of the sample plots also were made, but because the planting of *Pandanus* is highly erratic, estimates on the basis of the samples are less reliable. In Werua and in some of the other larger islets, *Pandanus* trees tend to be planted very thickly on the heaped up rubble dug from the puraka pits and often in the partial shade of

breadfruit trees where they constitute an understory. In the coconut dominant zone of Werua the per acre number of mature Pandanus amounted to 196, in the mixed breadfruit-coconut zone it was 68, and in the breadfruit dominant zone 515. On Parakahi, one sample area of 2,704 square feet had only a single Pandanus. Another sample in an equal area at the opposite end of the islet had five. Much of the Pandanus in the breadfruit dominant zone of Werua was of recent planting, since the trees, set 3-5 feet apart, were only from 6-12 feet in height.

The different vegetation zones mapped for the 33 islets of Kapingamarangi have been measured by hatchet planimeter for the larger areas and by 0.1 inch square grid counts for the smaller areas. The results of these measurements are shown in Table III. The sums of the various categories of land-use are indicated as follows:

Coconut dominant zone	157.03 acres
Mixed breadfruit-coconut zone	76.01 "
Breadfruit dominant zone (Werua-Touhou)	18.28 "
Puraka pits or fields	25.11 "
Total vegetated area	.276.43 acres

Applying the coconut tree counts for the various zones to these acreages gives an estimated 22,174 mature or bearing coconut trees in the entire atoll. Similar calculations for breadfruit with trunk diameters over 4 inches give an estimated 1,909 breadfruit trees most of which were of bearing size. While the sample counts are too limited for great accuracy, it appears probable that Emory's estimate of about 400 bearing breadfruit trees for the entire atoll is much too low. Emory's manuscript states that during the great storm of 1947 (1948?), some 201 bearing breadfruit trees or "about half the bearing trees" on the atoll were blown down. Emory did not make any actual counts, of course, and the fact that his informant's estimate of trees blown over by the storm was about three times the number recounted to us by the village secretary in 1954 places grave suspicion upon the accuracy of estimates of tree numbers made by the Kapinga people. There would appear to be at least two or three times the number of bearing trees estimated by Emory.

The mimeographed report for Ponape District Fiscal Year 1954 entitled Trust Territory Statistical Requirements, lists the following relevant figures for coconut trees in Greenwich (Kapingamarangi):

Total area in acres	332.8
Area in palm forests	320
Number of bearing trees	44,752
Number of immature trees	22,213

The number of bearing coconut trees given by the Ponape report is just twice that of our estimate. A starred note in the report indicated that the number was "by actual count". In the judgment of the present writer,

the above figures are completely erroneous in a number of ways and represent bad guesses on the part of the Kapinga land owners who probably never made any actual count of their trees and who also have little idea of exact dimensions and areas. In the first place, the total acreage of the vegetated land of the atoll is erroneously given, and is probably based upon rough area measurements from inaccurate small scale maps. The actual land area is 20 per cent less than the Ponape report's figure indicates. The difference between the total area and the area in palm forests given in the report would represent puraka land, presumably. That is, 12.8 acres would thus be in puraka land. This compares with the 25.11 acres of puraka fields mapped in 1954, or twice the area in the district report. Moreover, in the breadfruit zone and in the mixed breadfruit-coconut zone, a large part of the land is taken up by breadfruit trees to the exclusion of coconut. This may amount to as much as 40 acres or more in view of the large canopy of breadfruit trees in comparison with coconut trees. This obviously has not been differentiated in the figure for "area in palm forest". If the mapped puraka area of 25 acres is added to the possibly 40 acres of other non-coconut land, there remains only about 200 acres largely occupied by coconut trees.

That the figure of 44,000 mature coconut trees could not be correct can be deduced by the amount of tree crown area occupied by each tree. The average distance between the bases of coconut trees according to our measurement is about 21 feet, where the canopy is pretty much taken up by the tree crowns. This distance should, therefore, closely correspond to the diameters of the tree crowns, so that each tree would require an area of about 21 by 21 feet square or roughly 440 square feet. In a count of a relatively pure stand of palm trees from an enlarged aerial photo of Mokil Atoll,[1] the present writer found that in a rectangular area 200 by 400 feet in dimensions, or 80,000 square feet, contained some 140 mature coconut trees (including doubtful blurs). In another count from another part of the same photo, an area of 40,000 square feet contained 60 mature trees. In each case, an almost closed canopy of tree crowns indicated a closely set stand of coconut trees. Thus, 200 trees here required 120,000 square feet, or about 600 square feet per tree. Furthermore, measurement of individual tree crowns here yielded an average diameter of about 20 feet. From this, it would seem that if all competing vegetation canopy were excluded and coconut trees covered the entire land concerned fairly densely, there would be an average requirement of space per tree of between 440 and 600 square feet. Now, if 44,000 mature coconut trees were occupying approximately 200 acres of land, there would be 220 trees per acre, somewhat short of 200 square feet per tree or a little more than a third of the amount required at Mokil. Such crowding certainly did not occur on Kapingamarangi. It is equally obvious that there were no 22,213 immature coconut trees on Kapingamarangi where relatively few immature trees were in evidence, indicating little recent planting. In contrast to the Polynesians in Nukuoro Atoll northward of Kapingamarangi, the Kapinga people are careful not to allow too many mature nuts to lie on the ground and sprout. This may

1. See photo in Raymond E. Murphy's article: Landownership on a Micronesian Atoll, Geog. Review. October 1948, p. 601.

be merely a reflection of the greater need for food, which leads to some effort to keep the competition down that might reduce nut yields. If our estimate of 22,174 mature bearing trees were taken as correct, the number of square feet required per tree on a hypothetical 200 acres of pure coconut stand would be 385 and there would be some 110 trees per acre. This still represents considerable crowding. This compares with German plantings of coconut palm in newly cleared land in Kili in the Marshalls in 1893-94 at the rate of 78 per acre or in Likiep in 1891-92 at the rate of 69 per acre.[1] Plantings in British Malaya have been about 40 trees to the acre.[2] Newland in 1919 wrote that coconut trees should be spaced 30 feet apart in each direction.[3] Sampson in his very detailed and careful book on the coconut stated that the distance between trees should be four feet less than twice the length of a well developed leaf of a full grown bearing tree. (Since the leaf bends in a bow , the full distance of twice the length of the leaf need not be required). "Too close planting cannot be too strongly condemned," he wrote. "A tree must have full light if it is to carry a full crop of nuts ... The basis of value is not the number of trees to a given area, but the number of nuts which those trees can produce under proper management. It is safe to say that the ordinary copra varieties of coconuts should never be planted closer than 30 feet apart." Since the development of the crown was recommended as the basis for spacing, the most economical method is to plant at the three corners of an equilateral triangle. At 30 feet apart, this will give 56 trees to the acre against 48 when these are planted at the four corners of a square.[4]

It is obvious from the above that the coconut groves at Kapingamarangi, with 110 trees per acre planted about 21 feet apart on the average, and in many cases much closer together, represent heavy crowding. The 22,174 coconut trees of bearing size estimated to be on the atoll provide 52 bearing trees per person on the basis of the 1954 summer population of 426 people. The estimated 1,909 breadfruit trees with trunk diameters of over 4 inches provide an average of 4.5 such breadfruit trees per inhabitant on the atoll, calculated on the same basis.

Table III gives for each islet the total land surface under various categories of vegetation cover, the number of breadfruit trees, if there are any, and the number of bearing coconut trees. Touhou, the chief residential islet, represents a somewhat special case that requires an explanation for the figures applying to it. Because of the space occupied by houses and open yards on Touhou, the breadfruit dominant zone does not have as high a tree count either in breadfruit or in coconut trees. The transitional breadfruit-coconut zone separating the coconut dominant fringe near the shore from the breadfruit dominant interior is not too obvious or

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1. Germany, Reichstag, Denkschriften IV, Das Schutzgebiet der Marshall-Inseln 1893-94, Stenographische Berichte über die Verhandlungen des Reichstages IX Legislatur Periode III 1894-95, Berlin 1895, p. 497-500.
2. Kalaw, Maximo M., The coconut industry, The Philippines, National Assembly, Manila, 1940.
3. Newland, H. Osman, The Planting, cultivation and expression of coconuts, kernals, cacao and edible vegetable oils and seeds of commerce, London, 1919, p. 19.
4. Sampson, H. C., The coconut palm, the science and practice of coconut cultivation, London, 1923, p. 119-120.

significant and has been left out. In estimating the number of breadfruit trees, the lower per acre count for the Werua mixed breadfruit-coconut zone is used instead of that for the Werua breadfruit dominant zone. On the other hand, the lower per acre coconut tree count of the Werua breadfruit zone has been used for estimating the per acre number of coconut trees in the Touhou breadfruit dominant zone.

Note: In R. L. A. Catala's report on the Gilberts, he states that in an area on Tarawa where the density of coconut palms appeared to represent average conditions, he counted an average of 231 palms per hectare or 92 per acre. These were irregularly spaced. About the same count, 93 per acre, also was made on a regularly spaced plantation on Abemama (Makin). In village areas where houses and breadfruit trees were numerous he found in 14 countings an average density of only 115 palms per hectare or about 42 per acre. (Data from M.-H. Sachet's abstract translation of R. L. A. Catala, Report on the Gilbert Islands (mimeographed), Noumea, 1952).

Table III - Acreages in different vegetation types

Islets	Acres total area	Coconut Dominant Acreage	Acreage of Breadfruit-Coconut Zone	Number of Breadfruit Trees	Acreage of Breadfruit Zone	Acreage of Puraka Pits	Total Number of coconut trees
Torongahai	19.5	11.75	5.95	112		1.8	1640
Ringutoru	26.7	13.75	10.15	192		2.8	2070
Rikumanu	.9	.9					106
Turuaimu	2.0	2.0					231
Pepeio	.7	.7					82
Nunakita	14.2	11.6	2.55	48		.5	1460
Hukuniu	.9	.9					106
Parakahi	3.1	3.1					353
Werua	41.4	6.52	13.22	770	10.36	11.3	1612
Touhou	9.2	1.27		150*	7.93*		370*
Taringa	12.4	8.25	3.75	71		.4	1130
Pungupungu	.4	.4					46
Matiro	10.3	8.02	2.08	39		.2	1024
Matuketuke	1.0	1.0					116
Ramotu	3.5	3.5					405
Sakenge	2.3	2.3					266
Matawhei	.7	.7					81
Hukuhenua	5.0	4.66	.24	4		.1	541
Hepepa	2.3	2.3					266
Tipae	1.6	1.6					185
Tetau	7.8	5.38	2.02	38		.4	717
Nikuhatu	2.3	2.3					266
Takairongo	3.9	3.9		1			450
Tangawaka	7.0	5.2	1.5	28		.3	671
Hare	79.5	37.2	34.6	655		7.7	5930
Herekoro	3.8	3.74		1		.06	440
Tirakau	1.8	1.8					204
Tariha	2.2	2.2					254
Tiahu	.6	.6					69
Tokongo	1.8	1.8					208
Tirakaume	1.3	1.3					150
Pumatahati	6.3	6.3					726
Matukerekere	.03	.03					1
Totals	276.43	157.03	76.01	1909	18.29	25.11	22,174

*See explanation on page 34.

THE REGIONAL GEOGRAPHY OF THE ISLETS ON THE REEF

In the following section of the report, an elaboration of notes taken about the individual islets is presented. This elaboration is based upon field notes made by William Niering and the present writer either singly or in joint field observations. Errors of fact or generalization in the following account, however, are chargeable solely to the present writer.

The descriptions include information concerning the use of the islets for residence or workhouse sites, the existence of puraka pits, the shore and beach characteristics and effects on these of wave, tide and current action, the general surface soil character, the types, prevalence and condition of dominant and understory vegetation, and some aspects of or effects on human activity.

The order of arrangement is in accordance with the succession of the islets from north to south, beginning with Torongahai and ending with Matukerekere. Maps of the islets on the scale of one inch to 200 feet accompany these descriptions. For convenience in locating the section describing a particular islet, the following list gives the order of succession of the islets from north to south:

1. Torongahai (Figure 10)
2. Ringutoru (Figure 11)
3. Rikumanu (Figure 11)
4. Turuaimu (Figure 12)
5. Pepeio (Figure 12)
6. Nunakita (Figure 13)
7. Hukuniu (Figure 14)
8. Parakahi (Figure 14)
9. Werua (Figure 15)
10. Touhou (Figure 16)
11. Taringa (Figure 17)
12. Pungupungu (Figure 18)
13. Matiro (Figure 18)
14. Matuketuke (Figure 19)
15. Ramotu (Figure 19)
16. Sakenge (Figure 19)
17. Matawhei (Figure 20)
18. Hukuhenua (Figure 20)
19. Hepepa (Figure 20)
20. Tipae (Figure 21)
21. Tetau (Figure 21)
22. Nikuhatu (Figure 22)
23. Takairongo (Figure 22)
24. Tangawaka (Figure 22)
25. Hare (includes former Ruawa and Herengaua) (Figure 23)
26. Herekoro (Figure 24)
27. Tirakau (Figure 24)
28. Tariha (Figure 25)
29. Tiahu (Figure 25)
30. Tokongo (Figure 26)
31. Tirakaume (Figure 26)
32. Pumatahati (Figure 27)
33. Matukerekere (Figure 27)

1. Torongahai - 19.5 acres (Figure 10)

Has three working houses but no residence. One house is adjacent to the western part of the lagoon beach. Two others are in the middle section of the eastern channel shore. At the latter point a 70 feet long wall of coral blocks has been built out into the channel toward Ringutoru, apparently to trap wave and current deposited sand and debris in order to extend the land surface. These had begun to accumulate and to fill in the area on the seaward side of the wall. As the east side of Torongahai is

flanked rather closely by the large islet of Ringutoru (420 feet across the channel), protection is afforded from the more severe southeast storm waves. The northern end is exposed, however, and here wave erosion appeared to have reduced greatly a long triangular tongue of land narrowing seaward from the width of the islet. The former northward extent of the islet is outlined by two lines of consolidated beach rock. One, running from the west side of the islet in a northeasterly direction, has a dip toward the northwest of 13°. The second, running from the east side of the islet almost due north to meet the other line, has a dip of 7° toward south of east. Within these consolidated beach rock lines the unconsolidated accumulations of sand and rubble appear to have been scoured out.

Erosion severity on the north and northwest sectors of the shore is indicated by numerous fallen coconut trees. The soil around and under the root clumps have been washed out and the trees killed. Undercutting by wave erosion also has affected numerous other trees such as Guettarda, Scaevola, Messerschmidia and Hernandia. A thin covering of sand lies over the hard reef rock adjacent to the northern sector of the shore, but the beaches on the west, northwest, and northeast are of mixed sand, gravels and rubble with the exception of short stretches where sand may not be a significant ingredient. Except for a 130 feet section of the beach south of the boulder wall on the east channel, the rest of the beaches to the south and facing the lagoon are of sand.

The sandy character of the soils south of the puraka fields which occupy the central parts indicate that the islet is building lagoonward or southward. The seaward half of Torongahai has a gravel and rubble soil intermixed with humus. Several factors give indication of the lateral migration of the islet along the reef in a southwestward direction as well as lagoonward. On the southwest and west sides of Torongahai there appear to be two and possibly three beach ramparts roughly parallel to each other. The first is just back of the shoreline. A second rampart appears about 40 feet inshore of the high tide line, and the back shore sloping from this second rampart measures about 30 feet. Up to 150-250 feet inland a slightly raised though gently sloping ridge may once have been a beach rampart. Thus, the land must have built outward in a westerly to southwesterly direction. Niering made the observation while examining the islet that the northeast part of the islet is the richest in humus and grew the most luxuriant Nephrolepis fern, so that this probably was an indication of the greater age of the northern sector, while the younger land was found near the lagoon. It was also observed that the sandy backshore on the lagoon side measured up to 10-12 feet and that several stages of Scaevola growth graded outward toward the high tide line from the more mature to the young seedlings. Particularly rapid building up of sand was obvious at the southwest corner. Cordia found here overhung the sand 25 feet and was partly sand buried. Three bands of Scaevola grew here, the inner band reaching to 10 feet, the second band to about six feet, and the third band comprising new sprouts a foot or less in height.

Another indication of the southwestward building up of land on Torongahai may be provided by the situation of the puraka pits and the breadfruit zone. These generally are found pretty well centered in the islets or lagoonward of center. On Torongahai the puraka fields are only about 200 feet from the northeast shore, but some 500 feet from the southwest shore. Most of these pits appear to be quite old. If the northeast and southwest parts of the islet were of equal age, the construction of fields probably would have been better centered than they actually are, and would have included more of the southwest central part of the islet.

Coconut trees here generally are healthy and vigorous appearing, although on the island in the middle of the largest puraka field, some coconut trees have yellowish leaves. Large breadfruit grow over a large portion of the islet, particularly adjacent to the puraka fields. A number of these trees here appear badly injured by the excreta of nesting starlings. Limbs on which excreta drop are damaged and large branches then lose their leaves and die. Premna, Morinda, Pandanus form important understory vegetation. Ferns and grass also are luxuriant ground cover plants. No particular significance can be attached to the pattern of distribution of the understory which is highly man-manipulated here as on all the other islets of Kapingamarangi. Change from one property to that of another owner may result in sharp changes of undergrowth patterns. These patterns depend upon the inclination and diligence of the owners in cutting undergrowth or upon the stage of cutting or of regrowth. Hetau (Calophyllum inophyllum) are numerous along the lagoon shore although not of great size. Most of the trunks of the hetau were one to two feet in diameter. (One hetau tree observed by the writer at Nukuoro Atoll had four branches each about four feet in diameter).

2. Ringutoru - 26.7 acres (Figure 11)

Once said to be thickly set with habitations, it now has only six houses and a cement cistern, two being work houses on the western arm of the islet. The other structures include a canoe house, a dwelling or sleeping house, a work house and a shed which are grouped together with the cistern near the center of the lagoon beach and belonging to one family. Aesthetically, this is one of the most attractive of the islets in the atoll. It is the third largest. It differs from most of the other islets in having a relatively deep miniature lagoon of clear unsullied water about 1000 feet in diameter on its south side, enclosed by reef patches with a shallow channel through which canoes or small boats may reach the sandy beach facing the atoll lagoon. The two great southern lobes of this three-lobed triangular-shaped islet and the connecting beach between are formed of sand advancing lagoonward at a fairly rapid rate (i.e. averaging a foot or more per year). The eastern channel side of the islet with its incurving beachline shows evidences of long and severe erosion. The beach itself is comprised of loose fragments of rock and rubble, and the northern sections of this beach have two large dead coconut trees whose stumps have been washed out by wave action. A similar beach type is found on the western channel facing Torongahai, although a greater amount of gravels and rubble

lines the shore. The erosive forces along the shore are just as great and several dead coconut logs with root clumps lie on middle sections of this beach.

The soil in the two southern lobes of the islet are sands intermixed with humus up to 400 feet inland from the tip of the west lobe and up to 600 feet from the tip of the east lobe. In the rest of the islet the outer 100 feet or so of surface has a gravel-sized rubbly soil intermixed with humus. In this zone rubble beach ridges parallel the shore 10-20 feet inland. These are slightly elevated (perhaps a foot or so) above the inward lying ground. Within the central parts of the islet inward from this rubbly zone the ground is covered with many inches of black-brown humus overlying gravelly rubble which also has much humus. Within this central part and generally from 120 to 150 feet from the shoreline are located 13 puraka pits, most of them from 5000 to 10,000 square feet in area, although the largest is almost an acre in area. Around each pit the debris dug out has been piled into several feet high ridges which afford some protection to flooding by salt water from the lagoon during southerly storms. The seaward land area generally is somewhat higher than the sandy lagoonward parts. In the pits a rich mucky soil has been developed through rotted vegetation, coconut husks, and other debris used for fertilization. High waves from the south in the storm of 1948 (1947?) swept northward across the lagoon and flooded some of the puraka pits with salt water, killing all the plants. New plantings were made after the salt was flushed out by rains. The coconut trees in the interior of this islet are among the oldest, tallest and most flourishing on the atoll. Much of the ground underneath them is covered with a luxuriant mass of birds' nest fern (Asplenium nidus) growing waist high especially in the western central portion. With the exception of the 400-600 feet long lobes protruding southward toward the lagoon underlain with sandy soil, the parts of the islet inward of 75-100 feet from the shore form a zone of intermixed breadfruit and coconut trees. Some of these trees here are over four and five feet in diameter breast high from the ground and above the buttress roots. In the northern central parts of the islet the coconut breadfruit canopy is close to 100%. Similar cover extends over the central eastern parts of the coconut-breadfruit zone. The coconut palms here are over 100 feet tall and are only over-reached by the breadfruit trees by 15-20 feet. In the southern two lobes the coconut trees are dominant but form a lower stand, 75-100 feet high, indicating a more recent stage of planting and perhaps pointing to the more recent stage of land development in these lagoonward reaches of sand. The canopy on the eastern lobe is 75-100% as compared to generally 100% on the western lobe.

No pigs were observed on Ringutoru, but numbers of chickens were seen. These were quite wild and flew away like partridges when flushed suddenly from their nests.

3. Rikumanu - 0.9 acres (Figure 11)

Uninhabited islet lying on the seaward half of a 3000 feet wide reef, in dimensions 32 feet by 440 feet. Most of the islet appears to be underlain

with reefrock covered by one to three feet of rubble. Its shores are of severely eroded rock which on the lagoon end has been undercut for a distance of six or seven feet under a rock shelf two feet thick on top of which grows a coconut tree 25 feet high. In spite of the signs of severe erosion, the owner informed this writer that no noticeable change had been observed in the dimensions of the islet as long as he could remember.

The dip of the beach rock fringing the islet showed a 7-11° inclination toward the lagoon. A soil pit dug down to two and a half feet depth on Rikumanu showed a very rich humus intermixture with the rubble in which coconut tree roots formed an interlocked mass. Obviously an islet of this narrow width would have no fresh water lens, so that the vegetation must be entirely dependent upon the rainfall absorbed by the top two or three feet of soil.

The coconut trees on the islet were pretty closely crowded, were from 50-75 feet high, and provided a 50-75% canopy. A dense growth of Scaevola was the dominant understory while Pandanus and Morinda formed subsidiary understories. The owner stated that he cut down the Scaevola about once a year to keep it under control.

4. Turuaimu - 2.0 acres (Figure 12)

Without human dwellings and situated on the inner edge of the reef which here is some 3000 feet wide. Protected from easterly storms to some extent by its situation to the leeward of Nunakita Islet. Its lagoon beach is of foraminiferous sand. The northeastern tip facing the sea also had a small sand beach. The rest of the beach was of gravelly rubble, while the shores were severely eroded on the northwest and southeast seaward sides.

The soil throughout was sand mixed with humus. An apparently healthy stand of coconut trees 50-75 feet high provided a canopy of 50-75%. A relatively dense understory of Guettarda (50-75% cover) was accompanied by a lower understory of Morinda.

5. Pepeio - 0.7 acres (Figure 12)

Uninhabited. Gravelly beach on both seaward and lagoonward sides of its triangular shape, the third side facing the channel between it and Nunakita having a sand beach. Its soil is merely sand with a slight humus stain for the top two inches. It was built up by sand trapped by a coral wall on the seaward side constructed by the father of Materewe during 1919. Scaevola and Guettarda were planted at the time to hold down the sand and reduce wave wash. The islet gradually grew larger, and coconut trees were planted as the islet grew. In 1954 ten or more of these trees were producing nuts. These trees were still low, mostly under 25 feet, had yellowish green leaves and provided a canopy of 50-75%. Guettarda, Premna and Pandanus formed a sparse understory. Three young Calophyllum grew on the lagoon side.

6. Nunakita - 14.2 acres (Figure 13)

Uninhabited despite its relatively large size, although there is a sleeping house on the eastern side of the northern end which sometimes may be used. The reason for this possibly is that the Kapinga people did not or were not permitted to stay on it during the World War II period when the Japanese had their chief weather station here, with quarters and a concrete structure on the northern seaward end, as well as two steel radio towers now lying in wreckage on the ground. A two-story high concrete tower still stands on the southeast end of the islet at the water's edge. This had served as a meteorological tower. All the structures were bombed and wrecked during 1943-44.

The lagoon beach and adjacent land is of sand which has been gradually filling in a deep pool fronting the shore and bounded by shallow water 200-300 feet out from shore. On the east and west channel sides, the shores have been severely eroded and the beach comprises gravel and rubble thinly overlying rock. At the northern seaward end the eroded and stratified bedrock standing above the reef flat extends 210 feet northward of the shore in a patch of about equal width. The outer edge of this old bedrock here reaches within 290 feet of the coral terrace at the edge of the reef.

The soil is composed of sand intermixed with humus covering the entire southwest and south sections up to 350 feet inward from the southwest corner and 150 feet inland from the southeast corner. From this sandy area seaward the soil is mostly gravel-sized rubble intermixed with humus.

A zone of breadfruit trees intermixed with coconut trees occurs in the central portion of the southern half of the islet but north of the sandy zone. Two isolated clusters of breadfruit trees occur in the northern half of the islet, both near the eastern channel shore, the smaller one being adjacent to the sleeping house. The breadfruit tree trunks ranged in size from one to two feet in diameter. The taller and older coconut trees were situated in the lagoonward half of the islet, mostly running over 100 feet tall. On the seaward side the coconut trees were from 75-100 feet tall and more sparsely distributed. Partly this is because of the presence of the concrete and steel tower ruins. Some of the wreckage had become quite overgrown with a tangled mass of *Pandanus*, young coconut and other understory plants such as *Morinda* and *Premna*. *Morinda* was the dominant understory tree in the lagoonward half of the islet.

Only two small puraka pits existed on this islet, located within 200 feet of the southeast lagoon shore. In general, Nunakita appeared to be less tended than most of the privately owned islets. The seaward parts especially showed much neglect. Mosquitoes were encountered here in the largest numbers, without doubt owing to the breeding pools of stale rainwater green with algae and full of mosquito larvae that occurred in the concrete ruins.

7. Hukuniu - 0.9 acres (Figure 14)

Uninhabited. The only islet situated considerably to the seaward of another islet. An elevated ridge of bedrock forms a connection on the reef flat between Hukuniu and Parakahi. This may indicate an earlier stage of development when the two islets were connected to form one long islet like Nunakita. The subsequent erosional history may have brought about the severing of the attenuated islet into the present two islets 1225 feet apart. Eroded and jagged bedrock surrounds Hukuniu, jutting out seaward from the shoreline for about 25 feet and rising more than three feet above the reef flat. Small sand patches form the beach off the lagoonward tip. The soil is a coarse rubble with some humus content down to a three-inch depth.

Two representative coconut trees measured 42 and 59 feet high respectively. A complete count showed 85 coconut trees on the 0.9 acres, as well as three mature and two immature Pandanus trees. Morinda and Premna formed the spray-damaged understory vegetation while Guettarda and Scaevola grew on the outer fringes.

8. Parakahi - 3.1 acres (Figure 14)

Uninhabited. Sandy beaches on southwest and southeast leeward sides, the converging beaches building lagoonward into a sand spit. The beach on the north side is a thin veneer of rubble over the eroded bedrock. Undercutting is severe on the north side where parts of old Scaevola roots have been exposed by wave wash. The soil is rubble intermixed with dry humus except for the lagoonward sections within 30 feet of the high tide line where a sandy soil with less organic material occurs.

The coconut trees here are somewhat higher than on Hukuniu, averaging from 60-85 feet. On the basis of sample counts of two plots each 50 by 50 feet square, the number of mature coconut trees on Parakahi are 458, a dense stand. The understory is Guettarda and Morinda. On the north side a Calophyllum tree with a trunk diameter of 11.5 inches showed heavy leaf scarring from salt spray. A healthy Calophyllum stood on the sandy lagoon shore, however. Pandanus also is of some importance as an understory.

9. Werua - 41.4 acres (Figure 15) (Houses are not shown on map.)

The second residential islet connected at the south end of its lagoon beach with Touhou Islet by a causeway and road. Emory stated that in October of 1947 Werua had 183 of the atoll's population as residents, as compared with 293 for Touhou Islet, although it is more than four times as large as Touhou. Werua is the largest islet after Hare, but has a greater excavated area of puraka than Hare and more breadfruit trees because of a larger central area removed from salt spray and the saline sea edge, as well as because of a larger area of elevated land for breadfruit. It is surpassed in the number of coconut trees by both Hare and Ringutoru, however.

A roughly rectangular road runs around the central portion of the islet. The longest side, some 1200 feet, generally parallels the sandy lagoon beach at distances of 70-100 feet from the high tide line. On the south side the road runs closer to the shoreline, but on the north it runs from 300-450 feet from the shoreline. Most of the puraka fields are enclosed by the road, although seven puraka fields are found at the northern end outside the road rectangle.

Canoe houses and accompanying residences face the lagoon beach at closely spaced intervals, and it is here where most of the islet's residences are situated. The eastern and central parts of the islet are mostly without habitations. The elevation of the surface of the ground rises from the high tide line to about 5.4 feet near the central part of the lagoonside road. On the inward side of the road a level terrace constructed from the debris dug out of the puraka pits rises two to three feet above the road, and on this terrace which stands about seven feet above the level of the puraka field on the inland side are additional residences. Residences also border both sides of the south channel road but are not found along the road on the seaward side. Along the north channel shore are a scattering of houses which are spaced most closely near the north lagoon end of the islet. Two or three houses are situated at the shore near the northeast corner of the road rectangle. A single sitting house is located in the center of the seaward shoreline at the end of a path leading from the central road rectangle. A work house is found on the eastern side of the big puraka field on the rubble ridge in a dense thicket of Pandanus trees. On the same side of the large puraka field near the southern end is another work house or sitting house.

No wharf projects into the lagoon from Werua, since there is no need for it. The community canoe is housed in the Werua men's house which is situated near the center of the lagoon shore. Here is kept the longest canoe on the atoll, measuring about 57 feet, dug out from a single log. Inland and on the terrace across the road stands the small Roman Catholic chapel recently constructed by the 30 or so Catholic converts for their services. A brass bell mounted on a post outside the house is utilized for religious purposes.

The lagoon beach here is sandy and the offshore water is shallow. Seaward of the causeway in the south, artificial seawalls line the channel shore below which a rubble beach is exposed at low tide. This runs as far as the last residence on the seaward end. Further seaward the beach continues as a rubble beach while the shore becomes rocky. Most of the seaward beach is of this character, although some sand forms accumulations in small pockets at intervals. Just westward of the northeastern point there is a patch of sandy beach which is about forty feet wide. The north channel beach mostly is of rubble with occasional short stretches of narrow sand beach. The northern tip of the lagoon beach is of sand that is building up lagoonward.

The highest elevation above usual high tides measured in east-west traverse across the islet was 14.5 feet on the rubble ridge west of the northern end of the large puraka field. This drops quickly off the ridge to about 4-5 feet in the vicinity of the smaller eastern puraka fields and eastward across the road for about 100 feet where it begins to rise gradually to 8-10 feet elevation, 50 feet from the seaward beach (Figure 8).

Soil in the residential zone, except at the lagoon beach where it is sand, as on Touhou appears to be a layer of gravelly rubble spread on the surface by man which minimizes dust and dirt and provides for a firm clean surface. To a somewhat lesser degree than on Touhou the residential ground is kept free of leaves and debris, since Werua is not entirely residential and it is more difficult to keep clean. The road around the islet also is weeded and swept at intervals by teams of boys and girls under adult supervision. In the interior two vegetation zones, the soils correspond somewhat to what Fosberg describes as the Arno Atoll series,[1] and is similar to the soils in the interior of Ringutoru, Torongahai and parts of Hare, i.e., black or dark-brown loamy sands with some increment of gravels and with high organic content. Not all of the soil is of this type, however. The main constituent of the soil on the ridges surrounding the puraka fields is limestone rubble dug out of the pits. On the seaward side of the road rectangle most of the soil is of limestone rubble and debris. North of the small paths leading eastward to the seaward shore is a large patch of bedrock exposed on the surface and overgrown with Clerodendrum. That sea water percolates through underground cracks and holes of such rock several hundred feet inland here is indicated by several small abandoned puraka pits where puraka plants were unsuccessful apparently owing to saline water intrusions. In the puraka pits the soil is a muck through which the water of the fresh water lens is moved up and down by the tidal pressures.

Werua is the only islet having four rather clearly discernable vegetation zones (see Figures 8 and 15). These are arranged in a generally concentric zonation with the exception of the outermost zone of Guettarda and Scaevola which have been permitted to grow here only along the north channel and seaward fringe. Aside from this fringe zone a coconut tree dominant zone completely encircles the islet occupying the outermost 50-100 feet. Inward of this, breadfruit trees form an intermixed stand with coconut trees in a zone whose innermost bounds may roughly be delimited by a line running around the entire area of puraka fields and pits and coming close to their outer edges. The area inside this line is dominated almost completely by breadfruit trees among which coconut trees are much less prominent, but under which Pandanus trees occasionally form dense understory vegetation.

A vigorous and healthy tree growth is found throughout the islet and some of the largest breadfruit trees grow in the interior of Werua, the trunk of one of which measured 61.5 inches in diameter waist-high from the

1. Fosberg, F.R., Soils of the northern Marshall atolls, with special reference to the Jemo series, Soil Science, Vol. 78, No. 2, August, 1954, p. 101.

ground. Sample tree counts were conducted on a number of measured plots by William Niering and the present writer. Some generalizations from the results of the count have been given in a preceding section of this report under the heading: "The Food Producing Land". More detailed analysis is provided in Niering's report. As a residential islet, Werua differs from Touhou in that the larger part is non-residential and devoted to food trees and puraka pits. It also has rank and dense understory vegetation in the middle, northern and eastern portions of the islet in which Morinda, Premna and Pandanus all are prominently represented. This islet probably produces more Pandanus than any other islet on the atoll, much of it being recent plantings in the central parts. In the breadfruit tree dominant zone, the dense stand of Pandanus trees stood 3-6 feet apart but were only 6-12 feet high. Ornamental shrubbery around the residences is common, especially in the southern sectors of the islet adjacent to the road. Banana plants occur at rare intervals.

Birdlife is most prevalent in the northern sector of the islet where white-capped terns and noddies nest high on the branches of the breadfruit trees.

10. Touhou - 9.2 acres (Figure 16)

Main residential islet with more than half of the total population of the atoll making its home here. Emory listed the number of people resident on Touhou in October of 1947 as 293 out of the total of 527. Most of the religious and social activities are located here centered around the Protestant church and yard which in pre-Christian times (prior to 1910) was the focus of the cult ceremonies. Adjacent to the church yard is the islet's school-house and the wooden structure that forms the magistrate's (chief's) "office". These formed the living quarters and laboratory for the expedition in 1954. Both the house of the previous chief, King David, and the house of Chief Tuiai are adjacent to the church yard.

The entire surface of this islet is divided up into residential yards, although this interferes only partially with the space for growing coconut and breadfruit trees, since the houses sit under the shades of these trees.

Touhou is reported to be the result of man's work in building up the land plus the sand accumulation in the lee of the ocean waves and currents sweeping in from the sea in the east. The higher elevations are on the seaward side, while the lagoon shore lands are several feet lower. Two elevated areas northeast and southwest of the churchyard are over nine feet above sea-level, the former rising to twelve feet in a patch about 100 feet in diameter. A mound 30-40 feet in diameter to the seaward of this and overlooking the seaward shore also rises to 12 feet. The church yard lies at six feet elevation and the lagoonward side of the road around the islet roughly follows the six-feet contour. On the seaward side the road runs at 8-9 feet elevation above the usual high tide line. From about this height the shore on the seaward side drops off in a bluff to the high tide

line. A small sand beach about twenty feet long and ten feet wide has formed in the central section of the seaward beach, probably owing to the projecting platform built of coral blocks out onto the reef flat. Adjacent to this platform which supports a house is the community-men's outhouse, known as the "harepokuku" ('house of explosions'). Most of the shoreline here is artificial, comprising a series of built-up seawalls about four feet above high tide and providing protection against wave wash and erosion of the land behind. A women's community outhouse is situated on the north channel side of the islet. Both north and south channel shores for 150 feet or so from the lagoon shore have straight seawalls protecting the land behind. In the north channel area near the causeway is the only canoe house facing an inter-islet channel. Since the causeway obstructs acess to the lagoon, canoes housed here must wait for high tide to travel around Touhou to get into the lagoon. No canoe house faces the seaward side on this atoll. The lagoon shore rises from shallow water to a sandy beach on which the canoe houses are closely set next to the high tide line. The three feet contour runs 40-50 feet back of this line on the lagoon side.

Running out into the lagoon from the center part of the village street on the lagoon side is a wharf suitable for landing whale boats or small launches. This extends out about 175 feet beyond the high tide line and has about three feet of water near the end at low tide. The Touhou community men's house in which the community canoe for Touhou is kept is immediately adjacent to the base of the wharf on the north side. Projecting into the lagoon about 50 feet north of the wharf is a platform built up of coral blocks on which is set a residence house. A similar platform also is found 150 feet south of the wharf. Such structures reflect the crowded residential situation on this islet where additional living space can be had only by building outwards onto the tidal flats and beaches. From the northern end of the lagoon beach a causeway about eight feet wide and six feet high has been built across the channel to connect with the second residential islet of Werua. While the tidal flow continues through the interstices of the coral blocks used in the construction, sand is gradually accumulating on the lagoon side of the causeway and closing up the channel. In time and lacking any major storms, the seaward parts of the channel also will fill in so as to join the two islets into a single large islet.

Breadfruit trees are numerous on Touhou, while coconut trees and Pandanus trees are most numerous in the near shore fringes on the seaward side. However, because of the many houses, the number of trees of different type per unit area averages lower than on other islets. Understory vegetation here comprises mostly of Pandanus and a few ornamentals and some banana and papaya plants. The ground elsewhere is covered with gravelly coral for the most part. The elevated mound and the higher seaward elevations have several feet of fine organic soil exposed by wave erosion. The ground everywhere is kept clean of debris which is picked up daily and thrown over the bluff on the seaward side. Every stray leaf is picked up, so that little organic material returns to the soil. Because of the practice of cooking foods in ground ovens, the ashes from burnt coconut shells and husks form a constituent of the soil in the cooking areas.

Periodically, however, new clean sand is brought in to replace the old in the barbecue pits.

Emory stated that pigs had been banned from Touhou because of sanitary reasons and were not found on the islet during his stay. In 1954 however, a number of pigs were tethered to coconut trees in the beach areas both on the seaward and the lagoonward sides. Garbage and wastes all were thrown over the seaward bluffs near the men's outhouse or were carried out into the lagoon and dumped. Human wastes from the outhouses were scoured away twice daily by tidal waters, so that no sanitation problem was presented here. No outhouses are situated over the lagoon water as was observed by the writer on some other Micronesian atolls, but men and women wade into the lagoon for toileting and the more sluggish tidal action here leads to some fouling of the water near the beach. On the other hand, scavengering by fish disposes of wastes rapidly.

Water for drinking generally is collected on Touhou in above ground cisterns of cement construction at individual homesteads. A community well next to the school yard seven feet below the surface taps the fresh water lens. This water is used for bathing and washing purposes. Frequent bathing in the lagoon is common, and a bucket of fresh water from the well may be used as a rinse as well as for cooling the body during the day. Presumably, little of the fresh water used from the well is lost, since the run-off of washing and bathing promptly filters back down through the porous ground to the water lens a few feet under the surface. Surface evaporation is reduced by the cover of loose gravels.

The lack of dense understory vegetation and the open ground under the shade of the coconut and breadfruit trees permit the almost constant easterly breezes to pass across to the lagoonshore readily, cooling the air which can be very hot on the leeward sides of heavily vegetated islets in early afternoons. The eastern seaward side of the islet provides the most pleasant atmospheric conditions for man, since even during the afternoons when temperatures run over 90° F. there is a constant breeze. During early hours of the morning the coolness is such as to demand a sheet cover for comfortable sleeping. On Werua and other islets, houses are set on the warmer lagoon side because of the need for convenient nearness to the canoes which has paramount consideration.

11. Taringa - 12.4 acres (Figure 17)

Inhabited by at least four family groups, since there are four canoe houses fronting the lagoon, as well as nine other houses grouped around the various canoe houses. Its size and nearness to the main residential islet of Touhou across the north channel from it makes this a desirable residential area. A sandy beach faces the lagoon, but the channel and seaward beaches comprise a thin veneer of rubble lying on eroded bedrock. Coarse rubble is especially prevalent on the seaward beaches. Rapid lagoonward building of sand spits is occurring at both north and south ends of the

lagoon beach. This is aided in the north by a wall of coral boulders running 100 feet into the channel. A soil pit dug 50 feet from the central part of the lagoon shore reached bedrock 3.4 feet below the surface. At the center of the islet the bedrock was reached 5.75 feet below the surface.

A 100-feet wide strip of sandy soils with some organic materials runs along the lagoon shore, but in most of the islet, gravelly rubble intermixed with humus forms the soil. In a patch about 70 feet in diameter 150 feet from the southeast shore, bedrock is exposed at an elevation of only about 1.4 feet above high tide. Much of the islet is under 2.5 feet in elevation, although the central part adjacent to the puraka pits and the seaward sectors in the east rise to somewhat over 3.5 feet and in places to as much as 5.5 feet. A bomb crater near the eastern tip contains a fresh water pool owing to the exposure of the fresh water lens. Coconut trees in general appear vigorous and tall, mostly 75-100 feet high in the central and eastern part of the islet. Lagoonward of the breadfruit zone and within 100 feet of the shoreline they are only from 75-100 feet high and more sparsely distributed owing to the house clearings. Pandanus is the dominant understory in the vicinity of the houses and also in parts of the seaward side. Morinda and Premna are relatively dense understory plants in the center to the seaward of the puraka fields. Breadfruit trees with diameters up to 48 inches are found adjacent to the puraka fields. Some pigs and chickens are raised here, two pig pens being located adjacent to the north channel shore.

12. Pungupungu - 0.4 acres (Figure 18)

Uninhabited and connected by causeway to the islet of Matiro only 50 feet away. The causeway has accumulated sand on both sides which in a few years should result in joining the two islets into one.

Pungupungu appears to have shrunk from its former size, since large eroded beach and reef rock patches lie off the seaward side while no beach building in the way of sand or rubble accumulation appears to be taking place except the recent land building on the two sides of the causeway.

The coconut trees on the islet were from 50-65 feet in height, formed a 100% canopy and appeared healthy and flourishing. The rubble and humus soil also supported an understory of Guettarda and Pandanus.

13. Matiro - 10.3 acres (Figure 18)

Inhabited, having ten structures, several of which are sleeping houses, the others being work houses or canoe houses. The islet is a long one, some 1400 feet north and south, but only about 380 feet wide from lagoon to seaside. Its nearness to the residential islet of Touhou as well as its size have probably led to the construction of the residential houses.

All the beaches are sand overlying bedrock which, except along the lagoon shore, extends out seaward and along the south channel shore for a width of about 25 feet. In the vicinity of the tiny "satellite" islet of Pungupungu to which it is connected by a causeway, some tongues of bedrock 60-70 feet wide reach eastward up to 200 feet. A patch of bedrock also borders the south and eastern parts of Pungupungu. This extends seaward 187 feet from the shoreline and is 165 feet wide. Thus, erosion appears to be cutting back the islet from the seaward side.

On the lagoonside the sand which previously had been built up showed subsequent erosion eating away at the roots of established plants on the northern half of the beach. The southern half here showed no significant erosion at work, but rather was building up.

The only notation of coconut and understory vegetation taken was on the south end. This indicated a sparse stand here with only 25-50% canopy, but of flourishing trees over 100 feet high. However, a closer stand occurred in the rest of the coconut plantation. The chief understory on the sandy soil at the south end was Guettarda followed by Pandanus and young coconut plants.

A narrow band of intermixed breadfruit-coconut trees occupies the land immediately adjacent to and between the two small puraka pits set 400 feet apart.

14. Matuketuke - 1.0 acres (Figure 19)

Uninhabited islet 150 by 410 feet in dimensions elongated east and west. On the seaward eastern end a patch of bedrock the width of the islet extended 180 feet eastward along the reef flat. A narrow 10-20 feet wide strip of beach rock also fringed the north channel shore. In the channel about half way between Matiro and Matuketuke a 15 feet wide strip of beach rock stretched 320 feet seaward from a point near the seaward end of Matuketuke. Bedrock formed the beach all around the islet except the lagoonward half of the north channel beach which was of rubble and sand. Moreover, a large sand patch standing above high tide had formed lagoonward of the western tip of the islet and this was connected by a narrow neck of sand to the islet. The sand patch itself measured 44 feet wide and 176 feet long and was used at the time of visit for drying Pandanus leaves, indicating its position above high tide. In the central part of the sand patch a coconut sprout 1.5 feet tall had begun to grow, together with 4 seedlings of the Calophyllum. Provided there is an absence of severe storm waves, this patch eventually might be the nucleus of an additional piece of "permanent" land.

The vegetation cover on Matuketuke differed on the seaward third from the lagoonward two-thirds. On the former no understory vegetation existed on the very coarse rubble ground underneath which, intermixed with some humus, formed the soil of the entire surface of the islet. The coconut

trees on this third were under 50 feet high but seemed to be healthy looking. On the rest of the islet a denser stand of coconuts 50-75 feet high had a relatively sparse understory of Morinda, Pandanus, and Premna, with a further understory of Morinda sprouts. Land crabs are few on this as on most smaller islets. A number of new Pandanus slips had been planted by burying a branch with its leaf clump exposed above ground.

15. Ramotu - 3.5 acres (Figure 19)

Has two houses comprising a sleeping house and a shed for keeping coconut husk fuel dry. It is an elongated islet oriented east and west, with a sandy and pebbly lagoonside beach. The seaward and channel sides are bordered by eroded bedrock, 10 to 30 feet wide next to the channels, but widening seaward to 76 feet from the south channel. Off the seaward tip this rock extends for 88 feet seaward in a 200 feet wide strip somewhat wider than the tip of the islet. The beach on the south channel side is of sand and rubble which changes seaward to rubble that follows around along most of the north channel. A wall of coral blocks constructed for a distance of 25 feet from the northern lagoonward corner of the islet protrudes into the channel and has trapped a growing amount of sand on the channel side. The lagoon beach here appears to be growing rapidly with the accumulation of sand.

Coconut trees are dominant throughout the islet, but are low, ranging only from 50-75 feet tall and providing only 50-75% canopy. However, their appearance was good. The rubble intermixed with humus supports an understory in which Morinda dominates followed by Guettarda and Premna over most of the islet. The 100 feet section from the seaward beach, however, has Pandanus dominant, followed by Guettarda and Morinda. The undergrowth was relatively dense.

16. Sakenge - 2.3 acres (Figure 19)

An uninhabited islet of almost rectangular shape 580 feet long by 160-190 feet wide. 110 feet of the lagoonward end is composed of almost pure sand and the beach here also is sand. A line of old Scaevola marking the inner edge of this sand patch indicates an older lagoon shore and points to a rapid advance of the shoreline of about 100 feet lagoonward since these trees were young. From the terminal points of this line of Scaevola on both channel sides the shore is fringed by consolidated bedrock standing above the reef flat. This is only about 10-15 feet wide along the south channel but up to 66 feet wide along the north channel. Seaward from the eastern tip this extends about 80 feet over a width of 200 feet. There was no noticeable dip to this bedrock.

The dominant coconut trees were relatively low, from 25-50 feet on the sand near the lagoon but growing over 50 feet high on the rest of the islet. Two of the taller trees were measured to be 53 and 55 feet respectively. Except on the 110 feet section of pure sand near the lagoon the rest of the

soil was rubble and sand intermixed with humus. A pit dug into the soil here showed an 11-inch layer of rich dry brown organic matter grading into grey color. Except for the size there seemed to be no significant difference in the appearance of the coconut trees on the pure sand and on the sand with humus. No yellowing of leaves was apparent. Guettarda formed a dense understory, with some Morinda.

17. Matawhei - 0.7 acres (Figure 20)

Uninhabited. Fringed by eroded bedrock on all sides, with the western lagoon beach covered with rubble. The dip of the bedrock on the south beach is northward and inward 3-5° toward the islet, but on the north channel beach no dip in the bedrock was noticeable.

A rubble rampart rises just inshore all around the islet. The elevation of the lagoonward two-thirds of the islet is only one to two feet above high tide level. The ground is composed of rubble intermixed with humus. Coconut trees throughout are only from 25-50 feet high and are unhealthy in appearance, with yellowish green leaves. 50-75% canopy is provided by the coconut trees. A few Guettarda and Pandanus trees form the understory vegetation.

18. Hukuhenua - 5.0 acres (Figure 20)

Inhabited by two household groups and having six structures, three grouped at the north end of the lagoon shore and the other three at the south end. The canoe house at the south end belongs to Tomoki. A sand beach fronts the lagoon. The lagoonward 100-200 feet of both channel beaches are of rubble. Seaward of these rubble beaches cover eroded beach rock. On the south shore the dip of the beach rock is northward toward the interior of the islet, indicating the probable former existence of an islet or the old position of Hukuhenua immediately to the south of its present south shore. This is supported by the southward dip of the strip of beach rock in the middle of the channel between Hukuhenua and Hepepa 35 feet wide and paralleling the channel for 385 feet. That is, this beach rock and the beach rock exposed on the present south shore of Hukuhenua probably were the old channel beaches of a former islet during a period of standstill in the ocean level. Furthermore, the dip of the beach rock on the north shore of Hukuhenua is inward toward the south, possibly representing the south shore and beach of still another ancient islet whose north channel beach may have been the present south channel beach of Matawhei Islet 140 feet away where the dip was found to be 3-5° northward and toward the interior of Matawhei. From these and other similar situations noted, it is deduced that the shapes, sizes and distributions of vegetated islets along the Kapingamarangi reef once were greatly different. The islets, thus, may not be regarded as relatively static units of the landscape, but as constantly evolving elements which have undergone and are undergoing relatively rapid changes under the dynamic forces of erosion, accumulation, deposition and cementation.

On most of the surface of the Hukuhenua a dark, rich, moist, organic soil was observed. Only the central southeast sector from the edge of the breadfruit zone to the seaward shore was the soil a rubble intermixed with humus. A puraka pit occupies the central lagoonward part of the islet with an arc-like zone of breadfruit trees among the coconut trees around its seaward sides. Most of the coconut trees were from 75-100 feet tall, although smaller trees prevailed on the eastern seaward end. Pandanus everywhere was the dominant understory, occurring as planted trees especially dense in the vicinity of the dwellings. Hibiscus were numerous and comparatively large especially in the southeastern two-thirds of the islet. On the northeastern third Morinda followed Pandanus in the understory vegetation. Scaevola was most prevalent along the southeast shore.

19. Hepepa - 2.3 acres (Figure 20)

Uninhabited. Elongated in an east-west direction. It is 180 feet wide by about 600 feet long. A narrow rubble beach overlying bedrock runs along the seaward shores. Wider and deeper rubble accumulations line the channel beaches. A sand beach fronts the lagoon and also a short section of the north channel shore adjacent to the lagoon. Severe erosion of the shoreline has occurred especially on the south channel side. On the seaward part of this shore 10 to 20 feet of bedrock parallels the shore, widening at the eastern tip to 143 feet and extending seaward for 132 feet. In the north channel there also is a patch of old beach rock 385 feet long and 35 feet wide. The soil throughout is rubble intermixed with humus, except near the lagoon where sand and rubble with little organic composition indicate recent formation of the land. A soil pit dug in the seaward third of the islet near the center showed more than 15 inches of highly organic soil with dark brown colored soil down to 17 inches.

Coconut trees generally appeared healthy, but rise only from 50-75 feet high, providing a 50-75% canopy. Understory on the seaward third is formed by young coconut trees followed by Morinda and some Pandanus. Along the 50 feet strip next to the lagoon Guettarda followed by Scaevola forms the understory. In the rest of the islet Guettarda followed by Morinda and some Pandanus forms the understory.

An old Guettarda with a trunk 23 inches in diameter growing some 38 feet from the lagoon high tide line indicates the position of an old shore line generally parallel to the present lagoon shore. Coconut trees near the lagoon were only from 25-50 feet high. The taller trees on the seaward end measured from 65 to 85 feet.

20. Tipae - 1.6 acres (Figure 21)

Uninhabited. Like Pepeio, a man-made islet in its present state, but probably built upon the bedrock foundations of an older islet. This is indicated by the fact that bedrock standing a foot or two above the reef

flat extends eastward and seaward the width of the islet for almost 200 feet. An elongated islet, it is about 150 feet wide by 500 feet long. Just to the seaward side of the center of the islet lies a patch of loose coral blocks which may have been part of the original mound or wall constructed for trapping sand and enlarging the land. A 2.5 feet diameter stump of an old _Guettarda_, a tree generally found in the open sunlight of shore fringes, still sends sprouts from the roots growing from this pile of rocks. This circle of rocks also was the site of the ariki's house at one time, according to Chief Tuiai. A rubble rampart rises two or three feet above high tide 50 feet from the seaward tip of the islet. While some undercutting has occurred here, there also appears to have been some accretion of rubble and sand. This and the inland situation of the rubble rampart would seem to point to land building seaward during the recent period. An accretionary stage of the shore channelward also appeared to have been occurring on the north channel beach. Moreover, beach-building appears to have been occurring also on the southwest end of the islet. There are three separate beach ramparts roughly paralleling each other here, the innermost one being up to 100 feet from the present shoreline. Further supporting this probability is the fact that large, old _Guettarda_ stumps and a cluster of old decayed coconut root stumps line this rampart. Since _Guettarda_ likes sunlight and is generally found associated with beach fronts, the old stumps must once have been at the shoreline. The sandy ground here also supports the land-building supposition.

The coconut trees here are only from 50-75 feet high and form a 50-75% canopy, but they appear to be healthy and flourishing trees. Except near the lagoon shore where sandy soil appears, the soil mostly is gravelly rubble with humus intermixed. _Guettarda_ and _Morinda_ form a 50-75% cover of understory plants.

21. Tetau - 7.8 acres (Figure 21)

A north-south elongated islet with a small working house at the northern lagoon tip. The lagoon beach here is of sand, including the northern tip which is building up at a rapid rate. Bedrock exposures elevated above the reef flat extends off the northern seaward part of the islet for 20-50 feet while a much wider area of bedrock extends 130 feet from the south channel shore the width of the islet. Severe erosion occurs at the two channel sections of the shore, the debris from the south channel shore accumulating and building up the beach lagoonward at the southwest tip. The north beach rock dips lagoonward at an inclination of 7-8 degrees and shows the probability that the lagoon beach once was located here seaward of the present seaward shore. Two layers of rock show up in the dipping strata. The compact and fine grained lower layer is overlain by a cemented conglomerate of coral rubble in which the original shapes of the many coral fragments have been preserved.

The soil is gravel-sized rubble intermixed with humus throughout most of the islet, although on the seaward side a patch of bedrock 20 feet in

from the shoreline occurs. Four small puraka pits, the largest about 60 by 80 feet, have been dug in the center part in a north-south alignment. These pits generally are nearer the lagoon shores than the seaward shores, owing to the fact that the coarser ground of the seaward area is less impervious to salt water penetration than the lagoonward sands. Earthworms were numerous under the rotting coconut husk piles. Land crabs also were numerous, performing a valuable function in loosening and aerating the soil by the holes they bored in the ground.

A breadfruit-coconut zone occupies the area around the puraka pits, coming within 60 feet of the lagoon shore but not closer than 90-120 feet from the seaward shore. The breadfruit trees have trunks from 24-48 inches in diameter. The coconut trees inside this zone are from 75-100 feet high but do not appear as green and vigorous as the coconut trees in the coconut dominant zone nearer the shore. Pandanus is found on both seaward and lagoonward sides of the central puraka field. Morinda is most prevalent as an understory in the northern sectors of the islet but follows Pandanus on the eastern side and follows Guettarda in the southern sector. Hibiscus trees are numerous lagoonward of and adjacent to the puraka pits. Premna occurs in most parts in a scattered fashion. A ground cover in the form of grass appears on some of the elevated mounds west of the puraka pits.

22. Nikuhatu - 2.3 acres (Figure 22)

An uninhabited islet connected by a causeway to Takairongo to its south. The causeway was damaged by storm waves in its central portion and had not been repaired in the summer of 1954. A narrow islet only 170 feet wide, it extends east and west for 580 feet. Seaward from the east end a patch of bedrock the width of the islet extends for 154 feet, indicating a retreat of the shoreline lagoonward here. The causeway across the 200 feet wide channel to Takairongo has slowed the tidal currents through the channel and caused the deposition of sand in the channel. Gravel sized coral rubble intermixed with humus forms the soil of the entire surface with the exception of the seaward end where a strip up to 30 feet inshore is of cobble-and-boulder sized rubble.

Low coconut trees are found throughout. On the lagoon third the trees are from 25-50 feet high and on the rest of the islet from 50-75 feet. The canopy cover is from 50-75% and the leaves appear yellow green and less healthy than on most of the larger islets.

Near the lagoon end all underbrush has been cleared, but on the rest of the islet Guettarda is the dominant understory followed by Morinda. Few land crab burrows were noticed here.

23. Takairongo - 3.9 acres (Figure 22)

Uninhabited but has a small workhouse near the causeway that runs to adjoining Nikuhatu. Sand was accumulating near base of the causeway and was building out into the lagoon at both ends of the lagoon shore. The central portions of the lagoon shore, however, showed evidence of recent severe erosion. On the seaward side and the north channel side, eroded old bedrock extended 50 to 60 feet from shore. On the south channel side the bedrock only reached as far as the narrow part of the channel from the seaward side. A rubbly beach continued to the sandy lagoon corner of the islet. The southeast seaward shore was composed of unconsolidated rubble of cobbly size, while a rubbly beach covered the bedrock near shore on the north channel side. A small sand beach was developed for about 50 feet off the seaward point, while the lagoon beach was of intermixed sand and gravels.

A test pit dug in the center of the islet showed 8 inches of humus rubble and sand. The soil throughout was of rubble intermixed with humus. In the central part a small puraka pit 5 by 6 feet had been excavated. Coconut trees were from 50-75 feet high but formed a dense canopy and appeared to be healthy. Two breadfruit trees, the trunk of one nine inches in diameter, grew adjacent to the puraka pit which is situated 100 feet from the north channel shore. *Guettarda*, *Morinda* and *Premna* in respective order of importance formed the understory vegetation. A young undergrowth of *Morinda* was springing up underneath.

24. Tangawaka - 7.0 acres (Figure 22)

Has canoe house on north part of lagoon beach and a sleeping or work house on the southern part adjacent to a broken causeway connecting with Hare Islet 80 feet across the channel. Both lagoon ends have sand spits building out into lagoon, but the sandy shore between has been undercut by erosion recently. It appeared as though normal tidal waves and currents deposited beach sediment here, but that severe storms resulted in erosion and shore destruction. Several old coconut trees as a result of undercutting are leaning out as far as 40 feet from the base of the trunks. As a result of the causeway to Hare, sand and rubble have been accumulating and filling in the channel which is two to three feet deep in the narrow central parts even at low tide.

The accumulation is aided by a strip of old bedrock extending from within 150 feet of the Tangawaka end of the causeway in a direction about 10 degrees south of east. This tongue of reef and bedrock is 550 feet long by about 50 feet wide. The shore of Tangawaka opposite this rock has a sand and rubble beach that changes into a rubble beach and then to bare rock along the seaward parts. A rubble beach also is found along the north channel shore.

A gravel sized rubble mixed with humus is the prevalent soil throughout the islet except in the puraka pits and in the central parts east of

the large puraka pit. In the latter area a fine rich moist humus soil is found. The puraka pit is situated within 100 feet of the southeast seaward shore and is surrounded by a zone of intermixed breadfruit and coconut trees.

Guettarda is the dominant understory followed by *Premna* in the southern half of the islet where the two-three feet tall arrowroot plants also were abundant. Adjacent to the canoe house and within the breadfruit zone *Pandanus* has been thickly planted as the dominant understory followed by *Premna*, *Morinda* and some *Guettarda*. *Morinda* and *Premna* are dominant understories on the northern half of the islet followed by a scattering of *Pandanus*, *Guettarda* and, on the seaward side in the breadfruit zone, some grass. Some *Pandanus* also is found in the vicinity of the small house near the causeway. Breadfruit trees ranged up to 24-48 inch diameter trunks. In the central parts and adjacent to the breadfruit zones the coconut trees ranged from 75-100 feet tall and were healthy in appearance. On the east shore sectors and on the southern sandy tip the coconut trees were only 25-50 feet high. In the rest of the islet the coconut trees were from 50-75 feet tall.

25. Hare (pronounced as two syllables) - 79.5 acres (Figure 23)

Inhabited islet and the largest on the atoll, although not the widest. Its relatively great length, 1.29 miles compared with about 1,700 feet for Werua, the next longest islet, is not complemented by great width, since at the maximum Hare is only about 570 feet wide compared with about 1,150 feet for Werua. Most of its 29 sleeping houses, canoe houses and sheds are situated on the southern half of the islet, 14 structures being within 1,100 feet of the southern tip and the causeway connecting it with Herekoro Islet. Some pigs and chickens are raised in the area, the pigs mostly being kept tethered by ropes tied to a leg of the beast. Chickens run wild but are identified as to ownership by having various toes cut off at different joints.

Present Hare is the result of the joining of at least three islets into one through the filling in of two inter-islet channels near the south end. Time was not sufficient to permit sufficient soil examination to determine whether additional channels had been filled in in the formation of the northern and central sectors of the long islet. If this had been the case, this would have occurred a long time ago, since the oldest inhabitants on the atoll had no knowledge of such having occurred. On the other hand, the two former channels now filled in are of recent occurrence, the southernmost probably only since the last two decades, and the other at around 1858 when a storm is said to have piled up rubble closing the narrow lagoonward end of the channel between the then Hare Islet and former Ruawa Islet. The southernmost end of present Hare then was the islet of Herengaua, and these two sections of present Hare continue to be known by the names of the former islets.

The entire length of the lagoon beach and shore of Hare is sandy, although short sections near the houses on the south end have some coral gravels intermixed with the sand. The seaward beaches across the former channel openings on either side of former Ruawa are sandy but most of the seaward beaches are of gravelly rubble, mixed at places with sand. Occasional short stretches of the central and northern seaward beaches also may be of sand. The southern channel between Hare and Herekoro had filled in considerably with sand near the causeway built expressly for this purpose. Underlying the seaward beaches at the northern end is bedrock standing one to three feet above the reef flat and extending 25-30 feet from shore. The northern channel between Hare and Tangawaka has a rubbly beach except near the lagoon where the causeway has trapped quantities of sand. This channel is one of the deepest of the inter-islet channels, about three feet at low tide. When the tide is coming into the lagoon the current running through this channel resembles that of a rapid mountain brook.

Except adjacent to the lagoon or seaward shores, in the old causeway areas and on the ridges around the puraka pits, there is a rich moist organic soil many inches in depth. Hare, as well as the other larger islets, has high quality soils over much of its area and supports some of the most luxuriant vegetation. On the bordering ridges of the puraka pits the soils are rather coarse, being derived from the rock and rubble dug out of the pits. Breadfruit trees appear to thrive on such locations, however, perhaps because the porous coral debris has a great capacity for holding water while at the same time the elevation permits good drainage. In the filled in channels, the soil is sandy. The Herengaua-Ruawa channel site especially has almost pure sand, with little humus accumulation owing to the recency of formation of its land surface. In these sandy areas, breadfruit trees do not appear, while coconut trees generally are smaller and less healthy. One tree on the southern part of the seaward side of the old Ruawa-Hare channel was found to have lemon yellow leaves, while others near it had leaves less than a healthy dark green. Along the seaward shores rises a continuous rubble rampart except on the sandy former channel sections which runs the length of the former islet. A rubble intermixed with humus also is the soil in the northern 1000 feet or so of the seaward half of the islet.

Because of the largeness of Hare and the numerous people who own sections of land on Hare, the vegetation types here especially form no significant patterns. Different land owners treat their land differently. Some assiduously keep down undergrowth and even attempt to pull out grasses growing under the coconut trees. Others in an adjacent plot may let the understory grow rank and dense, so that one may have to push one's way through to cross the breadth of the islet. Generalizations are not entirely valid for such large expanses, but one may say that on the whole in the northern half of the islet _Morinda_ and _Premna_ have been permitted to be the dominant understory, while in the southern half _Morinda_ is more prominent. On the seaward shores _Guettarda_ appears sometimes thickly, at other

times in a scattered fashion along the entire length of the islet. Pandanus is most apt to be found on the fringes, especially the lagoonward fringes of puraka fields where they are more conveniently reached for carrying to the houses along the lagoon shore or for taking to canoes for transport across the lagoon. In the lagoonshore fringe, creeping vines one of which is of the morning glory variety, and grasses often become a heavy ground cover. The morning glory is pulled up and fed to the pigs, or pigs may be tethered to browse on it. The most common vine here is the legume Vigna marina. Grass was very prevalent in fringeparts of the sandy old channel sites. On the seaward half of the northern 2000 feet of the islet Pandanus is the dominant understory.

Hare has the largest area in which breadfruit trees grow, some 34 acres, almost half the entire area of the islet. Some are among the largest on the atoll, i.e., over 4 feet in diameter waist high from the ground and above the buttress roots. Some 655 breadfruit trees with trunk diameters of over four inches are estimated to grow in the coconut tree-breadfruit tree zone occupying the middle parts of the islet except at the former channel areas. Coconut trees in general are tall (in the 75-100 feet and over category) and are healthy in appearance in most of the islet. Lower stands of coconut trees are found in the former channel areas now filled in. In the former Herengaua channel area the coconut trees are only from 25-50 feet tall and most of these represent young trees planted since World War II. In the former Ruawa-Hare channel, the coconut trees are from 50-75 feet in the central and lagoonward parts but taller on the seaward northern half of the old channel. Along the lagoon shore, younger trees growing on the sandy shore also are lower than the trees in the center and seaward sides. Finally in the central section of the islet, severe bombing by American planes during World War II resulted in the destruction of numerous coconut and breadfruit trees, so that most of these types of trees in this section are younger and lower trees. This shows up clearly in silhouette pictures of the skyline of the islet from the lagoon. Northward of here is an underground concrete lined munitions or gasoline storage pit used by the Japanese during World War II. In 1954 the pit was half full of fuel oil taken from the post war Japanese fishing boat stranded on the reef which later was refloated and re-named the "Lucky" by the Kapinga people. Nearer the northern tip are two concrete cisterns above-ground formerly utilized by the Japanese but now damaged and abandoned. A large bomb crater near the lagoon shore has created a water-filled pit here in which some mosquito larvae were breeding. Partial filling in of this crater might bring it into use as a puraka pit, although perhaps it is too close to the lagoon shore. Puraka pits are strung out in the center along most of the length of the islet, but are not found on the recently added section comprising the former southern islet of Herengaua, which originally was too small apparently to support an adequate water lens.

Relics of World War II remain on the lagoon beach near the northern end in the form of three wrecked Japanese seaplanes and several engines,

all badly corroded. Since these planes stand partly buried by sand, it is obvious that the beach here is building up rather than eroding, although the southern part of Hare's lagoon beach along the length of former Ruawa shows evidences of severe erosion of the shoreline. Ten stumps and logs of overturned coconut trees lie next to the shore here, while one coconut tree still grows on a two feet wide neck of land projecting 10 feet lagoonward of the rest of the shoreline. On the other hand between 45 and 80 feet of now vegetated sandy land has been added lagoonward from the old shoreline of former Herengaua since the now almost buried causeway with former Ruawa was constructed. The new causeway to Herekoro is further extending this land building.

26. Herekoro - 3.8 acres (Figure 24)

Has a small working house on the northeastern lagoon side tip connected by a causeway built in 1953 connecting with the southern end of Hare (former Herengaua). The house belongs to the Protestant pastor Leon, and the causeway was built by him to trap sand and debris to fill up the channel and create new land. The causeway was about six feet high and five feet wide, made by piling up loose coral blocks. Some of these were recently live coral, so that the blocks must have been hauled from the lagoon by canoe. During January of 1954 high waves from rough weather destroyed the central part of the causeway which was reconstructed in the summer of 1954. A small puraka pit 60 by 50 feet was located on the lagoon-side of the center of the islet. One breadfruit tree with a 14" diameter trunk was standing on the east corner of this pit.

On the seaward side bedrock outcrops a foot or two above the reef flat extend up to 25 feet from the shoreline, while along the north channel it extends lagoonward in a ten feet wide strip. On the south channel shore 6" diameter boulders grade into smaller rubble and gravel toward the lagoon. Both north and south corners of the lagoon side of the islet are formed of sand in process of building up. The central part of the lagoon shore shows an equilibrium position between erosive and building forces.

The lagoonward third of the islet has sandy soil with some humus. The north channel side up to 100 feet inland from the shoreline has a moist fine soil with high humus content. The rest of the islet has a soil of rubble with humus content.

Coconut trees with 75-100% canopy coverage occupy most of the islet. A patch 100 feet in diameter adjacent to and seaward of the puraka pit showed less than 25% canopy, and an old stump of a large breadfruit tree stands here. In the north channel sector of the islet young coconut trees prevailed, badly spray damaged and from 50-75 feet high. The coconut trees in the rest of the islet were mostly from 75-100 feet high.

In the lagoonside of the islet between the puraka pit and the shore, _Premna_ formed the dominant understory as it also did in the center patch around the old breadfruit tree stump. In the rest of the islet, _Morinda_ was the dominant understory. _Pandanus_ was found scattered from the center of the islet northward to the channel. A moderate scattering of arrowroot was found within 100 feet of the seaward shoreline. Here as on most of the islets _Guettarda_ and _Scaevola_ formed an outward fringe and understory to coconut along the shore. A small lone _Calophyllum_ stood on the lagoon shore. A few _Hibiscus_ and some low grasses also were found.

27. Tirakau - 1.8 acres (Figure 24)

Uninhabited N-S elongated islet. Sandy beach along lagoon shore. Bedrock exposure for 10-15 feet wide strip off north channel shore, extending along seaward half of channel. No notation for south channel shore features.

Healthy stand of coconut trees averaging 75-100% canopy, 75-100 feet tall in central part of islet, 25-50 feet on seaward end, and 50-75 feet on lagoon end.

Premna understory predominates except on lagoon third where _Pandanus_ leads. In central part _Pandanus_ follows _Premna_, but on the seaward end dense _Guettarda_ follows. Young _Morinda_ forms a lower understory with 25-50% leaf coverage of all except seaward third where _Clerodendrum_ thrives on rough rubble and bedrock.

Rubble with humus forms the soil cover, although on the seaward third bedrock exposures occur with the rubble.

28. Tariha - 2.2 acres (Figure 25)

Uninhabited. Sandy beach on all sides except for the southwest channel beach and on eastern seaward corner where jagged bedrock is exposed. The two corners of the lagoon beach are building sandspits lagoonward. Coconut trees were 50-75 feet high and appeared in relatively good condition. The understory particularly on the seaward fringe was a _Scaevola-Guettarda_ combination. Some _Premna_ and _Pandanus_ as well as _Scaevola_ formed an understory to the coconut trees.

29. Tiahu - 0.6 acres (Figure 25)

Uninhabited. 20 feet wide beachrock fringes all except lagoon side where a sand beach is advancing in two prongs lagoonward. On the southwest side some sand and rubble have accumulated over the beachrock. The coconut trees from 50-75 feet high forms a 50-75% canopy. The fronds are

yellow-green and salt damaged. The soil is gravelly rubble intermixed with humus. Guettarda forms the fringe vegetation, although there is some Scaevola on the lagoon beach fringe.

30. Tokongo - 1.8 acres (Figure 26)

Uninhabited. Seaward southeast shore is of jaggedly eroded bedrock. This changes to a rubble beach on the northern corner. Here the exposure to the easterly waves and currents has resulted in the rounding off of this corner of the islet and the building up of a sand beach and spit lagoonward on the western corner.

A single breadfruit of small size was found about 90 feet from the seaward shore. The coconut trees were from 50-75 feet tall, providing a 25-50% canopy which on the seaward side showed the damaging effects of salt spray, but otherwise appeared healthy. Bedrock overlain with humus formed the surface of the ground in the central part of the islet. Sand and rubble intermixed with humus covered the rest. Digging with a stick showed a 7 inch top soil of rich brown color above a grey layer. In the lagoonward parts the layer with rich humus was 18 inches thick. Morinda was the dominant understory, followed by Premna in a dense stand. A few Pandanus also were found.

31. Tirakaume - 1.3 acres (Figure 26)

Uninhabited by people and with no dwellings. Like Pumatahati, it was also once a sacred islet which has become community property, and is also similarly inhabited by nesting birds.

The seaward half is fringed by clastic limestone or bedrock extending from the rocky shore for 20-50 feet. This appears to be old beach rock and is eroded in a jagged fashion. Moreover, the seaward third of the islet has a surface of broken beach rock, some of which is upturned and in chunks from 3-5 feet in diameter. The eastern channel shore is especially severely eroded and undercut with a beach of sand and rubble. A large Guettarda tree here has had its sprawling roots washed free and overturned by the waves. Rubble and sand form the beach on the west channel side and on the lagoon side. The soil is coarse rubble with some humus content. A tongue of sand was building up and extending lagoonward in a westerly direction from the west corner of the islet.

Somewhat yellowish-green leaved coconut trees covered the seaward third, growing from the porous rock and providing a 50-75% canopy. These trees mostly were from 25-50 feet high. On the other two-thirds of the islet the trees were from 50-75 feet high and more flourishing.

The understory in the rocky seaward part was a combination of young coconut, Pandanus, Morinda and on the south side a dense thicket of Clerodendrum. On the rest of the islet Guettarda formed the only significant understory.

32. Pumatahati - 6.3 acres (Figure 27)

Uninhabited, but having a community house in state of neglect on the western lagoon end of islet. The islet formerly was a sacred islet used for cult purposes. Since the people have been Christianized, the islet has become community property.

The beach area exhibits the effects of exposure both to the easterly and southerly storms. The southeastern shores show severe erosion undercutting the fringe vegetation. A rampart of very coarse coral blocks has been built up inland 35-50 feet. Some of the blocks are up to one foot in diameter, indicating the force of the storm waves from the southeast. A 25 feet wide strip of eroded old bedrock extends along the southern seaward side of the islet. On the eastern channel side the beach is mixed sand and rubble. The west channel beach is quite bouldery and the shore is strongly undercut. An unusually high beach rampart of coarse cobbles also extends along the lagoon shore, 15-20 feet inland. This lagoon shore is exposed to storm waves from easterly storms in contrast to those of most of the other islets. On the southwestward seaward side severe undercutting of the shore has washed the soil and rubble from the base of old coconut trees, leaving the stumps exposed. On this side the ground is clear under the coconut trees in contrast to the heavy fringe of *Guettarda* and *Cordia subcordata* that forms a wide zone on the northeast seaward and channel sides. *Cordia* also forms a dense cover along the eastern two thirds of the lagoon shore. On Kapingamarangi, *Cordia* appears to be largely restricted to these shore sections of Pumatahati Islet. A 100 feet section of the western channel shore facing Matukerekere has a *Scaevola* border adjacent to the community house.

Contrasting ground and soil conditions occur on the islet. In a 100 by 200 feet patch at the center, the soil is a rich black-brown humus with no rubble intermixture. A 50 feet diameter patch of bedrock is exposed between this and the east channel shore. The rest of the islet has a soil that is of coarse rubble with particles up to one inch in diameter intermixed with some humus. This islet and the adjoining islet of Tirakaume have large bird populations because both formerly were rarely visited by people owing to the sacred character of the islets. The birds therefore roosted or nested here in large numbers in the trees and the soil has a high guano content in contrast to the general lack of bird deposits in the other islets. These two islets generally can be identified by the swarms of birds soaring above them. On the ground under rotting piles of coconut husks were numerous land crabs, while scavengering hermit crabs swarmed the beach fringes..

The general impression left by the vegetation is that of neglect as contrasted with the privately owned land on other islets. Large numbers of young coconut trees in the understory show that nuts have been left to

sprout pretty much as they fell. A much denser undercover of other vegetation also appears here among which Premna, Pisonia sprouts and occasional Pandanus were the most prevalent. Upon the occasion of one visit the writer picked up half a dozen exceptionally large nuts from the southern seaward side of the islets, which however were found to be very light in weight, containing little juice and meat. The cause for this condition was not ascertained. This may be related to the high guano content of the soil beneath the trees. Nuts examined on the uninhabited island of Gaferut where two coconut trees grew in soil with excessive guano content showed similar characteristics.

The neglect in clearing the understory vegetation and in keeping down excessive competition among coconut trees may be attributed to the fact that no one owns this land privately. At intervals, which probably are far between in time, the village council decides on a community work expedition to Pumatahati and Tirakaume to clear underbrush, reap coconuts, cut logs and rods for house construction or gather coconut leaf fronds for thatching roofs of community buildings such as the school, church, dispensary, and the like.

The community house on Pumatahati is merely a shelter for work parties or for fishermen who may wish to spend the night. During the summer of 1954 the thatched roof was dilapidated and no longer provided effective protection from rains.

33. Matukerekere - 1400 sq. ft. (Figure 27)

Uninhabited sand patch which formerly was much larger. It now has only 0.03 acres of land above high tide, but once this amounted to about 0.7 acres and this was covered with coconut trees. After a storm washed the islet away (apparently in 1858) no coconut trees were planted here until 1919 when ten coconut trees were established. In 1948 (1947?) another big storm from the southeast scoured out nine of these trees, leaving the lone adult palm seen in 1954. The only other significant vegetation were four young trees planted in February of this year which had grown to about five feet high by summer. Their leaves were yellowish and showed the effect of salt spray as well as of lack of fresh water around the roots.

That the extent of Matukerekere once was much greater was evident from the eroded beach rock extending far beyond the present high tide line of the sand patch. A measurement of the dip of the rock showed an 8-15° downward dip toward due magnetic north. This obviously is a relic lagoon beach the present position of which south of the islet indicates the northward, lagoonward migration of the islet. Pumatahati 1455 feet to the east provides Matukerekere some protection from eastern storm waves, so that the most important destructive agents in pushing the islet northward and lagoonward are the storms from the south.

LAND, HOUSING, FOOD AND LIVELIHOOD

Emory has made an extensive study of the problems of land ownership, canoe and house ownership, food sources and fishing activities, as well as the social customs of the Kapingamarangi people. A summary of some aspects of these problems and activities as described by Emory and confirmed by the writer will be given at this point together with some observations made by the writer during 1954. For detail and amplification, Emory's report should be consulted. For material objects and aspects of Kapingamarangi life, Peter Buck's work on the Material Culture of Kapingamarangi is a full study of great value.

Land.

All land on the atoll is privately owned except the following: Matukerekere, reserved for fishermen's use; the former sacred islets of Pumatahati and Turuaimu, which now are community property; the area formerly occupied by the cult house on Touhou which now is occupied by the Protestant church and the school; the men's house on Touhou and that on Werua; and, finally, one or two wooden-frame houses formerly occupied by resident Japanese administrative officers on Touhou now considered public property by the District Administrative office. Land is divided among heirs or given to friends, but leasing or selling of land or houses is not practiced. According to Emory, there are no disproportionately large land holdings, while everyone has a place in which to live and from which to draw their sustenance. Women have the same kind of rights as men in land ownership.

Housing.

Kapingamarangi has preserved its traditional type of house with a thatched roof made of woven panels of coconut leaf fronds tied down to the roof rafters with coconut husk fiber cords. The frame underneath the roof is constructed of various types of wood. Corner posts are generally of *Guettarda* trunks, with cross beams of coconut or *Pandanus* logs. Permanent walls are found on most of the sleeping houses, with vertical rods set a few inches apart and tied to cross pieces, the lower ends of the rods being set into holes in *Pandanus* logs. *Pandanus* mats then are added for privacy and protection from wind and rain. The aspect from the outside is charming and superior both from the aesthetic and the comfort point of view to the corrugated tin-roofed shacks that have appeared on other islets in the East Carolines and on Ponape. It is far cooler under the thatched roofs than under tin or wood in the hot sunshine of midday. Only a half dozen houses on Kapingamarangi have the rusty tin roofs, including the wooden board house in which the expedition made its headquarters, and the shed in front of it. Canoe houses are the largest structures in size and may be as large as 20 feet by 60 feet in ground dimensions. Residences are smaller.

Food and livelihood.

Since puraka will only grow in the centers of islets that have a significant fresh water lens and since islets large enough for this are few, not all land owners own puraka land. Some also may not own or have rights to breadfruit trees. Because of the scarcity of land for producing such foods, puraka fields often are divided up into very small parcels by rows of stone slabs set on end or by footpaths.

As population has become more dense and land fracturing has increased, land disputes also have become more prevalent. Formerly disputes would be settled by fighting, but now they are settled through public hearings under the chief. If a solution cannot be reached, the District Administration holds hearing and decides the matter.

On the residential islets of Touhou and Werua, lagoon frontage is important since canoes must be housed at the lagoon edge. Canoes must be sheltered for preservation, and it would be inconvenient to carry the heavy dugouts more than a few yards each time use of them was required. Many canoe owners without the necessary land frontage on the lagoon may have canoe houses on the land of relatives or friends.

Breadfruit trees serve the double function of supplying food in the form of fruit and of supplying trunks for dugout canoes. The Germans counted only 47 canoes in 1910. In 1950 Emory counted 122 in use and 122 canoe hulls stored away in canoe houses which appeared no longer serviceable. According to Emory, it takes 20 years for a tree to reach full bearing stage. Trees used for canoes are generally old trees past their prime for bearing fruit, and such trees are from 70-80 years old. There are several varieties of breadfruit trees growing on Kapingamarangi (see William Niering's report on vegetation). Emory stated that the "native" Kapinga variety bears for about two months, then rests three or four months before bearing again. In 1950 one bearing period for the native variety was finished by September 15. The fruit of a second variety introduced from Nukuoro was expected to begin ripening by the middle of November. When breadfruit ripen in larger quantities than are desired for current eating, they are cooked, dried and rolled into rolls which are then covered by Pandanus or coconut leaves and bound with cord. In this state they may be preserved for several years. Breadfruit seeds also are eaten after being cooked.

Coconuts furnish several varieties of food, depending upon the stage of ripeness of the nut. When about full-sized but still green, the crisp but soft husk under the tough outer skin next to the stem may be eaten raw. At this time and before the inside meat hardens, the juice has a delicately sweet flavor and forms an excellent substitute for water. A practiced person with a sharp machette can hold the nut in one hand and chop off several chips of the husk at the stem end without cutting the hand, thus exposing the soft shell for drinking. When a number of green

nuts are to be used for drinking, however, the Kapinga men will sharpen a stake, push one end into the ground or prop it against a support and then husk the coconut on the other end. After this, it is a simple matter to cut a hole in the stem end of the coconut for drinking. When drained, the green coconut may be split or broken open. A wedge-shaped slice of the husk cut off to be used as a spoon is fashioned to scoop out the jelly-like flesh which at this stage has an entirely different consistency and flavor from the mature nut. The latter contains juice that generally is not drunk because of the poor flavor. At the mature stage the meat is cut out in chunks and eaten or the meat may be grated on a shell or aluminum grater attached to a stool with a neck. The grated coconut is used in various concoctions in cooking. From it also is made coconut cream for cooking purposes. In making this, skeins of coconut husk cord are mixed in with the grated coconut and some water and then twisted between the hands, thus forcing the oily cream out of the coconut shreds. When the mature coconut is allowed to sprout, the spongy mass filling the nut can be eaten although, according to Earl Stone who studied the problem on Arno, this is not an economic use of copra nuts. On Kapingamarangi as on other atolls coconut palm sap is collected in bottles from the flower stalk, the tip of which is cut before the nuts are formed. Two beer bottles full per day may be collected. The sugary sap is used for feeding babies, for cooking use, and for a fermented alcoholic drink.

Productivity of coconut trees and the situation in Kapingamarangi.

No systematic or reliable figures have been compiled on the productivity of coconut trees on Kapingamarangi, but some inferences may be obtained by a study of figures from elsewhere. The nut yield per tree varies widely in different parts of the coconut-producing realm and in accordance with soil properties. In Brazilian plantations production numbered from 15-40 nuts per tree per year.[1] On three plantations in Bahia the averages were 25, 35, and 56 nuts respectively.[2] In Malaya where trees were planted 40 to the acre, the nut yield averaged 50 per tree per year, while in the Philippines the accepted average has been about 30 nuts per tree per year.[3] In Ceylon trees well planted and looked after were said to yield an average of 60 nuts per year, but with manuring and attention under favorable conditions a far higher yield could be obtained. A German source stated that in East Africa the average production was estimated at 75 nuts per year per tree but that palms well cared for would yield 100 nuts per year.[4] Sampson stated that on the Malabar coast of India where the soil was relatively poor "An average of 60 nuts per

1. Bondar, Gregorio, Instrucoes Bara Plentio e cultivo de coquiero, Boletim da Seccao de Fomento Agricula da Bahia, No. 2.
2. Brazil, Ministry of Agriculture, Producao agricola, 1948.
3. Kalaw, Masimo M., The coconut industry, Manila, 1940.
4. Curtis Gardner & Co., Ltd., The cult of the coconut, London.

tree is nothing out of the usual, while an average of 90 nuts per tree is not uncommon. Taking good and bad trees, a large number will produce as many as 128 nuts".[1] Bondar asserted that the "best averages" in Africa and Oceania were from 120-150 nuts per tree per year.[2]

It must be pointed out that most of these figures pertain to plantations where spacing of coconut plantings at least on the better plantations have been systematically and somewhat scientifically worked out. Earlier in this paper it has been noted that the best spacing (on the basis of leaf crown requirements) would allow some 56 trees per acre, and that on some German plantations in the Marshalls the number of trees per acre averaged between 69 and 78. The "best averages" for Oceania probably would be from such better spaced plantations than from the crowded spacing of some 113 per acre of coconut land that is estimated to prevail on Kapingamarangi. However, if it were assumed that the Kapingamarangi average amounted to less than the best, say 100 nuts per tree per year instead of the "120-150" of the "best averages", then the average production of the 22,684 trees of bearing size would be in the neighborhood of 2,268,400 nuts annually or 11,342 nuts per acre of producing land.

How much copra this would make also is uncertain, since the size and weights of nuts varies again with different soil and moisture conditions. A comparison of coconut composition by weight of different components given by Sampson indicates the differences on representative samples of rich and poor soil:[3]

Coconut components by weight in grams

	On rich soil	On poor soil
Husk	520	329
Shell	201	145
Meat	453	298
Water	384	101

From this it is seen that the nut meat grown on the poorer soil is only about 65% the weight of the nut meat grown on the richer soil.

The fresh meat of the coconut contains 45% of water and the greater part of this has to be driven off in the manufacture of copra.[4] Assuming that all except 5% of water is driven off, there is thus a shrinkage of 40% in the coconut meat, and only 60% of the original weight remains in the dried copra. The copra per nut on the rich soil in the table above, therefore, would be 271.8 grams and that on the poor soil 178.8 grams, or 0.6 pounds and 0.39 pounds respectively.

The average production per acre of coconut plantation per year on Nauru on the basis of production figures for two years (1905-1906) amounted to about 2,423 pounds of copra.[5] If the plantings here by the Germans

1. Sampson, H. C., The coconut palm, London, 1923, p. 181-82.
2. Bondar, op. cit.
3. Sampson, op. cit., p. 183.
4. Ibid, p. 223.
5. Germany, Reichstag, op. cit.

were at the same rate as the average on their plantations on Kili and on Likiep, i.e., 73.5 coconut palms per acre, the average yield per tree would be about 33 pounds of copra. If the nuts were large and weighty, as in the case of Sampson's nuts from the rich soil, the palms here must have yielded only about 55 nuts per tree per year. On the other hand, if the nuts were lighter and poorer as in the case of Sampson's nuts on the poorer soil, then the palms must have yielded as many as 84 nuts per tree per year in order to get the 33 pounds of copra per tree per year. If it be assumed that Kapingamarangi soils are superior to those of Kili and Likiep these figures give some indication that the assumed 100 nuts per tree per year for Kapingamarangi may not be too far out of line.

If the above Nauru copra yield of 2,423 pounds per acre were used as a comparable basis for calculating Kapingamarangi yield, then the 200 acres of coconut producing land would be producing only 242.3 short tons of copra annually. On the other hand, if the calculation were made on the basis of the assumed 33 pounds per tree on Nauru, the higher figure of 113 trees per acre estimated to prevail on Kapingamarangi would mean that the average annual production would be as high as 374.3 short tons, provided the denser crowding of trees were sufficiently compensated for by higher fertility of soil.

/R. L. A. Catala gives a mean consumption per person at Tarawa Atoll of 4 nuts per day and a mean consumption per pig of 3 nuts per day. He also estimates the use of 2 palms for each 5 persons in toddy production. Taking this consumption into account and dividing the weight of copra exported by the average weight of 0.34 lbs. of copra per nut, Catala estimates an annual production per tree of a mean of only 23.1 nuts. This seems a rather low estimate, and Catala states that the figure used for pig consumption is low, that no account has been taken of nuts lost in the brush, destroyed by rats and coconut crabs, fed to chickens, or sold or given to outsiders by the land-owners. Finally, Catala admits that the figures for density of trees and the copra yield may not be representative enough. Moreover, the 1947 census report for the area's population and number of pigs also may suffer from inaccuracies./ [1]

On the other hand, if the two figures given by Sampson for the coconut meat per nut for large and small nuts are used in calculating Kapingamarangi's production at the rate of 100 nuts per tree per year, then the total cured copra production would amount to between 443 short tons on the basis of small nuts and 680.5 short tons on the basis of the large nuts. Thus, we have the following possible figures from which to choose for the approximate amount of total copra production possible from Kapingamarangi:

242.3 short tons calculated on acreage basis and Nauru yields
374.3 short tons calculated on basis of 33 pounds per tree
443 short tons calculated on basis of Sampson's small nut
680.5 short tons calculated on basis of Sampson's large nut

These figures are highly hypothetical, to be sure, but they still provide a useful yardstick for evaluating the Kapingamarangi situation with

1. Data from M.-H. Sachet's abstract translation of R. L. A. Catala, Report on the Gilbert Islands (mimeographed), Noumea, 1952.

respect to food production from coconuts, with respect to the food requirements, and with respect to the effect of exporting varying amounts from the atoll. If, as Chief Tuiai informed us, Japanese exports of copra from Kapingamarangi Atoll reached as high as 300 (metric) tons of copra in at least one year, and if the production averaged 374 short tons or less per year, then it is understandable why famine occurred during the drought years 1916-1918.[1] Tuiai stated that individual shipments during the Japanese period came to 40 to 70 tons. We know that the Japanese sent a ship to the atoll about three times a year, so that the average yearly export then may have been between 100-200 tons of copra. This drain must have forced a much greater reliance by the people upon fish, puraka, and breadfruit, and two of these at least are subject to effects of the occasional droughts and storms. On the other hand, if good prices were paid the people, they probably were able to import some foods such as rice. Tuiai gave the writer the impression that the economic situation or at least the trade situation had been better during Japanese times than in the post-war period because of better copra prices.

Kapingamarangi's coconuts varied in size greatly. Some of the "drinking nuts" given us were half the size of others. The soil conditions under which the coconuts grew varied from almost pure sand to soil with extremely rich humus content. An average sized nut thus should be assumed for Kapingamarangi. If the Kapinga people during the Japanese period exported willingly as much as 100-200 tons of copra annually, the atoll production probably was higher than the lower two figures given of the possible total amount of copra production from all the coconut trees on the atoll. An average of the higher two figures seems more likely to represent the true situation, i.e., about 561 short tons per year.

Whatever the true situation may have been, the exports of copra since the American administration took over have been relatively low, only 48 short tons for 1954. Yet there did not appear to be any significant waste of nuts. The fallen coconuts were picked up often enough to keep the ground fairly clear and few were allowed to sprout where they fell. This must mean that most of the unexported copra was consumed either by people or by the pigs. However, there were relatively few pigs on the atoll, as indicated by the count of 288 in 1946, and they were relatively small. The inference would be that most of the coconuts are required for consumption by the populace unless substitute foods can be had. Export of additional amounts of copra can be made without much food loss if other types of food are imported to take its place at regular intervals. Actually, this is what occurs, the Kapinga people import moderate quantities of rice, and some flour, as well as small quantities of luxury foods. The amount of such trade would depend largely upon the relative prices for the exported copra and for the imported foods. With higher copra prices and lower rice and flour prices, the atoll people can afford greater exchange while preserving their food adequacy. There appears to be little surplus beyond local food requirements, however.

1. On the basis of Catala's estimate, almost exactly half of the coconut plantation of Tarawa Atoll is consumed on the atoll and half is exported.

Puraka may be boiled in water or may be baked in coconut casseroles in barbecue pits, often mixed with breadfruit or with coconut cream. The dried coconut husks and shells form the primary fuel source for cooking.

Fishing.

Fishing provides one of the important staples of the diet. A great variety of food fishes are available, both of the reef and the open sea variety. Many ways of catching fish are utilized. In the shallow inter-islet channels, adjacent land owners may construct V-shaped fish traps from coral blocks and boulders, with the open end of the V facing the seaward side. The other end facing the lagoon will have an opening a foot or so wide leading into stone enclosures in which the fish swimming toward the lagoon can be readily caught. Throw nets are utilized along the reef at night in conjunction with torch fires. Generally this fishing is done near the outer edge of the reef in the vicinity of the algal mat. Spear fishing in channel areas or in conjunction with fish drives along the reef across the lagoon from the village is a common practice. Hook and line fishing is done both in the deep water of the lagoon and outside the pass on the open ocean not far from the reef. In the latter area tuna or bonito is a common and much prized fish.

Two types of fishing are quite spectacular. One is the catching of flying fish at night, and the other is the community fish drive. Catching flying fish by torch light formerly was led by the ariki or priest, according to Emory. Now individual canoes go on the trips, but two or three canoes may be raced along abreast by the paddlers. Outrigger canoes outfitted for the catching of flying fish embark with an expert wielder of a small scoop net attached to the end of a 12-feet long tough but light Hibiscus pole. A number of six feet long bundles of dried coconut fronds bound tightly into torches are carried on the outrigger platform. Two to four people go along to paddle the canoe. This enterprise is done only when there is no moonlight, since the reflected light of the moon from the surface of the water makes it difficult to see under water. The men set sail in their canoe just before sun-down, so as to arrive near the ship passes just as darkness sets in. It appears that the flying fish enter the passes to sport about or feed in the shallow water of the lagoon near the passes shortly after dark and return to the open ocean before dawn. In this shallow water, the fishermen have set a number of stakes into the coral rock and sand and erected small racks or platforms upon which they lay their sails after sailing across the lagoon. The sails are cumbersome and interfere with the fishing operation.

Here the paddlers take over and send the canoe in great sweeping circles over the shallow water of the lagoon near the passes. A coconut leaf torch is lit by the scoop net wielder who balances himself at the bow of the canoe, his torch held high in his left hand, while his strong right arm carries the pole and scoop net. As the canoe begins to pass over schools of flying fish, reflected light from their backs enables the fisherman at the bow to see them just under the surface. Many flying fish

now will break the surface and sail past or over the canoe. The net wielder is busy scooping fish out of the water at this time. A swoop, a twist of the pole to pin the fish in the net, a half-turn toward aft and a flick of the wrist slams the fish into the ten inch slot that forms the open belly of the dugout canoe. In another few seconds this is repeated, and so on as long as fish remain in sight and reach. Sparks from the torch shower backward toward the paddlers as the canoe skims along. When the school is lost, another circle over the area is made. Then when enough fish are caught or when the men are tired, the canoe is paddled to the sail rack, the mast and sail are set up and the canoe is raced home. Hundreds of flying fish have been caught by a single net wielder in a few hours upon occasion. About 60 flying fish were caught in 3 hours by the crew of the canoe in which this writer rode. Each fish was from 8 to 10 inches long. The catch was divided equally among the fishermen involved. Flying fish may be smoked and dried in the sun before eating, or they may be baked after being wrapped in breadfruit leaves.

Community fishing drives are open to all men who have canoes or wish to go along. These drives take place regularly on Saturday morning but may occur before any special celebration or feast. Each of the two residential villages have a fishing master, and the base of the operations is the men's house on each of these two islets. The fishing master or leader is considered the guardian of the net for his village. He has charge of portioning out the work in making and repairing the net and directs field operations, and he commands the community canoe. However, he is at the direction of the atoll chief as to when joint operations are to take place such as for special celebrations.[1] During 1954 when this writer went along to observe this type of fishing upon two separate occasions, ten or twelve canoes with about 30 men went on one such drive. Twenty-one canoes with over 60 men and boys went on the second.

Peter Buck has described the equipment and method of community fishing done with a trap or purse net[2] while Emory has described fish drives in which a mere naked rope is used, held at ten to fifteen feet intervals by men who gradually move inward, restricting the circle. The fish appear frightened of the shadow that the rope makes in the water and will not readily cross such a shadow. With this rope the fish are driven towards pockets of shallow water on the reef. A circle of men closes in gradually, while the fish mill about in the center. Finally, a coconut fiber net is thrown around the cordon of men. The men step outside the net which then is used to bag the fish and to haul them aboard the leading canoe. Sections of the reef are named individually for locations where fish drives are made.[3]

Two types of fish drives were observed by the writer in 1954. These drives were made across the lagoon from the villages. In both cases

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1. Emory, op. cit.
2. Buck, Peter, The material culture of Kapingamarangi, 1950, p. 226-230.
3. Emory, op. cit.

V-shaped net traps made of coconut husk cord, suspended from wood floats and weighted down with stones at the bottom were set up on the lagoon side edge of the reef with the open end of the V facing the reef. A cotton twine purse net formed the end of the trap into which the fish were finally driven. In the first type of drive the men fanned out from each side of the V into a great circle perhaps two hundred yards in diameter armed with steel fish spears and light poles with which to beat the water. The men most distant then began closing in, walking slowly at first and hitting the water with their sticks to frighten the fish toward the net trap. When the circle closed in to about 100 feet diameter, all the men were leaping and stumbling over the coral toward the net, splashing and shouting in a frenzy almost as great as that of the various schools of fish which were finally panicked into the net bag. This drive was repeated about ten times until it was thought enough fish had been caught. Each time the fish were hauled into the leading community canoe from Touhou. This type of drive was essentially the same as those described by Buck, although those which he witnessed were in the inter-islet channels or near the various islets on the east and southeastern parts of the reef. It is in this type of operation that the men suffered frequent coral scratches on their legs which bear numerous scars from infections.

The largest drive observed in 1954 was made for a community farewell feast for the expedition near the end of August. About 60 men in 21 canoes joined in the drive which took place around the southwestern pass area of the reef. Several small drives of the above described method were first made from the north along the reef toward the pass. The great drive of the day utilized long ropes of coconut fiber to which were tied green coconut leaves at intervals of about a foot. The canoes were tied up and anchored to a large coral patch bordering one side of the deepest pass and on which the V-shaped net-trap or purse-net had been set up. Swimmers took one end of the rope and swam with it across the mouth of the pass. Then the rope now stretching across the pass was gradually moved lagoonward up the pass. The waving green leaves and the shadow cast by them and the rope presumably frightened fish to a considerable depth to flee into the lagoon before the advancing rope. Gradually the rope was let out as swimmers towed it into the lagoon in a great loop extending from one end of the V-trap. Another rope also tied with green leaves at the same time was extended from the other side of the V-trap and carried by swimmers in an equally great loop into the deep water of the lagoon. The rope was kept from sinking by swimmers holding it at intervals near the surface. The two ends of the loop were joined and tied at a point perhaps a thousand feet or more from the net trap, thus forming a huge circle of rope several thousand feet in length.

The men holding the ends of the rope at the mouth of the trap under the direction of the drive master now began pulling in the rope as the swimmers moved toward the trap. The rope was hauled into canoes as it was pulled in. Finally, the loop shrank inward onto the patch reef itself, while the circle of men closed in with it. In the meantime the men used their poles to poke the fish out of holes in the coral rock and to

drive them toward the net.. By this time several large schools of fish were dashing madly about seeking an escape from the cordon. With a final rush, the fish were driven into the purse net and the trap closed. The men and boys wearing simple Japanese goggles, - pieces of glass framed in wood tied together with string, and armed with spears, now searched the holes in the coral rock under water for fish that had sought refuge there. Numerous fish were caught with spears during these drives.

Upon the conclusion of these drives, the pastor or an elder said a prayer of thanks and the canoes set sail and raced for home. The community canoe from Touhou which carried the fish bagged in the drive was emptied of the fish and carried into the canoe shed. The fish now were divided into as many individual piles as there were participants in the fishing expedition, each pile having the same number and approximately the same size of fish. The fish then were given to the various participants and were carried home in coconut leaf baskets made from a single frond to be cleaned and cooked by the women.

Most of these reef fish caught were from 12-16 inches long, and numerous varieties were included in the catch. No exact record was kept of the number caught during the various drives in the summer of 1954, although during the two drives described individual piles of fish divided among the participants numbered about ten fish. In eight such drives described by Emory, the number of fish caught varied from less than 300 to over 1600. There was no great correlation between the number of men involved in a drive and the number of fish caught, although for a successful drive enough persons must go along to form relatively large circles without too great gaps between persons. These fishing expeditions no doubt served a social and recreational function as well as an economic one, and were looked on by the men as full of sport and fun.

Note: A summary account of the life and environment of the atoll of Kapingamarangi is provided by the excellent article by Ralph E. Miller: Health Report of Kapingamarangi (Atoll Research Bulletin No. 20, September 30, 1953). In this, the problems of food and water supply, diet and sanitation are clearly presented, as well as a detailed study of the health and diseases, and the local remedies and remedial practices. While no specific references have been made to this article in the present study, the writer has familiarized himself with its contents and has found confirmation in field observation for many of the aspects discussed in the article. The fresh water problem, one of the most important on coral atolls, has not been discussed at length in the present report, although it is briefly described in the sections on Climate and on The Regional Geography of the Islets on the Reef under the subheading TOUHOU. The reader is referred to the section on water supply in Miller's article and to the detailed discussion of the fresh water lens in the report of Edwin McKee, the geologist of the 1954 field team.

The trade of Kapingamarangi.

Little is known of the pre-European contacts of the Kapingamarangian people with outside peoples, but because of the isolation of this atoll and the fact that they early had lost the art of building large seagoing canoes, it is improbable that there occurred other than rare chance visits by stray canoes such as those of the Marshallese. The first European ship visited the atoll shortly after 1870 and before the departure of the Marshall islanders. What the mission of this ship was is not known, although it may well have been a trader. A second ship known only as "John's" ship entered the lagoon after most of the Marshallese had sailed away and took the last of the invaders with it. This ship was a trading vessel searching for beche-de-mer (sea cucumbers) which were dried and taken to sell in China where they were in demand for exotic soups. A chant collected and translated by Emory indicates this mission: "Two boats landed in the surf, looked on the reef (for sea cucumbers) in quantity". The crew of the boats were uncertain of their reception by the Kapinga people and pointed their guns at an inquiring group of men, but were pacified when the Kapingans offered them a gift of drinking coconuts. Whether any trading was conducted is not told.

A third ship may have been the Fire Queen which was said to have come from New Zealand in 1877. The fourth ship reaching the atoll possibly was Sir Cyprian Bridge's vessel, the "Espiegle". The fifth ship is remembered as having brought Captain "Harry" Williams who stayed with his Nauru wife on one of the islets and supervised the curing of beche-de-mer. The sixth ship brought Tiaki (Jack) Lee with his native wife Nuri from Nukuoro. He was responsible for the introduction of the valuable puraka plant which has become one of the staples of diet and which supplanted the smaller taro plant in the pits and dugout fields. Following the visit of the seventh ship, an eighth, the schooner Kiritie from Rarume, Rabaul, New Britain, brought the Englishman Lui Patterson, apparently in 1892. All of these ships no doubt introduced various outside goods and commodities hitherto strange to the natives. Thus, when the first steamer arrived under the German administration, some individuals already had the tobacco habit as indicated in the following translation of a chant by Emory: "Pauroti (seeing the ship) rejoiced, because he was on his last carefully conserved tobacco. If so-and-so (is on the boat) and is kind, there will appear bundles of tobacco". Today, although smoking is frowned upon by stricter members of the Protestant church, cigarettes are in great demand and form one of the objects purchased from traders. The market for beche-de-mer, on the other hand, appears to have disappeared, while the natives themselves do not eat it.

Prior to the German administration there appears to have been little trading in or export of copra, the dried coconut meat. Chief Tuiai told

the writer that 70 years ago many people lived on the islet of Hare in contrast to only a few today. Houses occupied much of the land, so that coconut trees were much fewer in number. Most of the coconuts were eaten and few were made into copra. After the great massacre by the Marshallese, the vacant houses provided land for a large increase in coconut trees. Since the population did not increase as rapidly, there was an ample surplus for export, and the Germans sent occasional small freight and passenger ships, the "Langeroog" and the "Sumatra", operated by the Norddeutscher Lloyd Company to Kapingamarangi. These were small enough to enter the lagoon. Some of the types of objects acquired by the Kapinga people were mentioned by the members of the German South Sea Expedition of 1910: "They have received some objects most favorably and through purchase or imitation they have become quite familiar sights. This is especially true of deck and rocking chairs, white suits, and colorful cotton materials. The natives also like all kinds of furniture and household goods, e.g., chests of drawers, bedsteads, cooking pots, lamps, sewing machines, tables and chairs. On the other hand, they scorn some goods, e.g., European fishing gear".[1] By 1954, a change had occurred in the latter attitude, since steel fishing hooks and fishing line were much desired and highly prized.

In exchange for such foreign objects there was little aside from copra which the Kapinga people had to offer that was desired by the outside world. No information is available on the amount of copra which on the average was exported or taken from the atoll during the German administration. By the beginning of the Japanese administration, the new coconut plantings on Hare had come into the height of their bearing stage, while the Japanese also made efforts at extracting large amounts of copra which, at least during the drought period of 1916-1918, brought about severe food shortages.

During the Japanese administration, the "Ponape Isolated Isles Steamship Line" operated a trading route starting from Ponape and calling at Pakin, Ngatik, Nukuoro, Kapingamarangi and Oroluk, covering the distance of 1,240 miles in 24 days. Three trips per year were made on this run.[2] Tuiai stated in 1954 that the Japanese informed him that annual copra export at times had reached as high as 300 (metric) tons. Tuiai's records were destroyed during the American bombings in World War II, but he said that he recalled individual shipments of 40 to 70 tons. Under the American occupation prices had not been as good as during pre-war period when world market prices were higher. This and perhaps the increased population during the American administration has resulted in much decreased copra shipments. The highest single shipment in this recent period has been about 30 tons, and some shipments have been as low as 3 tons. The

1. Emory, op. cit., as translated from Eilers.
2. United States Navy Department, OPNAV 50E-5, Civil Affairs Handbook, East Caroline Islands, 1944, p. 117.

shipment made on the occasion of the July visit of the District trading ship in 1954 amounted to about 15 tons. Tuiai also ventured the opinion that the trees, which were in their prime during the Japanese period, now were past their best bearing age. Information obtained from the Ponape District Administration indicates that the total amount of copra exported from Kapingamarangi in 1954 amounted to only 48 short tons. As in the pre-war period, the post-war market for Micronesian copra has been in Japan.

In an effort to supplement the meager economy of Kapingamarangi and other Micronesian islands following World War II, the U. S. Navy and subsequently the ITC (Island Trading Company) together with the Trust Territory Administration solicited handicraft work from the islanders for outside sale, mostly in the United States or in U. S. military and naval activities. A successful sustained market for handicrafts other than for Pandanus mats has not yet been developed for Kapingamarangi. The Kapinga men are excellent model canoe builders and fine craftsmen in the making of a variety of objects fashioned from wood, such as wooden bowls, and coconut grating stools, while their women make some of the finest Pandanus and coconut mats for table or floor in the Pacific and do fine work in basketry. Perhaps the largest order for such handicrafts was placed in the history of the atoll in 1954. At this time ITC placed an order for 100,000 sq. ft. of Pandanus floor matting for the U. S. Navy Housing Office. This order apparently was filled in four months by the Kapingamarangi people through strenuous effort involving long hours of night work for some of the women. Many women worked late at night by the light of coconut shell fires or kerosene lamps. An inquiry about such industrious application and what seemed like unhealthy overwork brought out the response from Tuiai and others that this was an "order" from the American administration to produce so many square feet of matting, and they felt obligated to fill it in time to meet the schedule of the trading vessel which was sent to Kapingamarangi once every two months. The price paid for the mats amounted to 9 cents per square foot, so that this order netted the atoll inhabitants a total of about $9,000 or the equivalent of about $21 per capita. This represents a considerable sum of cash available to the atoll inhabitants for the purchase of trading goods. No attempt was made to ascertain the types and amounts of purchases the Kapinga people made from the outside.

Our scientific team members also had placed orders for a variety of handicraft objects including canoe models, place mats, kamit boxes (fishermen's waterproof boxes), bowls, coconut grating stools and models of such stools, baskets and "Panama" hats. Some additional articles of these types were sold to the American sailors from the destroyer escort on which the team departed, while other articles were sent to Ponape for sale through one of the commercial companies there. Such outlets for Kapingamarangi crafts should be considered exceptional, however. Moreover, the trading vessel which had been under charter by the District Administration at Ponape had proved expensive to maintain, so that in 1955

the Kapinga run had been discontinued. This left the isolated atoll with only the services of a small (about 60 feet long) former Japanese fishing boat owned and operated by some Kapinga people making infrequent and irregular runs between Ponape and Kapingamarangi. While this is in line with the Trust Territory Administration efforts to channel the trade into local hands and thus provide more income to the native peoples, this move also has resulted in decreased opportunities for outside contacts and services. At the same time, this compels the inhabitants of Kapingamarangi to revert to a higher degree of self-sufficiency. As an instance, the two local storekeepers had run out of matches prior to our departure so that boxes of matches were prized gifts, although the Kapinga people make fire by rubbing sticks when necessary.

The introduction of Christianity liberalized many former restricted aspects of the economic and social life while introducing new restrictions upon certain liberal aspects of former practices. The former belief in the sacredness of breadfruit trees and canoes provided the ariki with religious sanction for his control over acquisition and use of these important economic items. The ordinary population had to secure permission from the ariki through the intermediary of the secular chiefs in order to cut down breadfruit trees for canoe building and also required similar permission to utilize canoes. The difficulty of securing such permission resulted in the restriction of most of the fishing to reef areas reached by foot, according to Chief Tuiai. This also must have restricted across-lagoon travel between such places as Hare and Ringutoru, so that people on one of these islets often would be unacquainted with people on the other. Christianity brought the abolition of such priestly sanctions and improved economic welfare. Anyone owning his own breadfruit trees could thereafter cut them for canoe making at will, so that mobility and fish production increased. Emory expressed surprise at the great increase in canoes between the time of the German expedition and 1947 when there were 122 canoes as compared with only 47 in 1910. This increase most probably was related to the abandonment of the ariki religious control.

Moreover, two of the islets, Pumatahati and Turuaimu, in the southeast part of the reef once were taboo except for cult purposes. All the rest of the land had been privately owned and parceled out with the exception of these islets, Matukerekere, and the cult house on Touhou. The adoption of Christianity resulted in the transformation of these islets into community property which provided a source for building material for community projects such as the school and dispensary buildings, the community men's houses, outhouses and the like. From time to time, community parties organized by the chief would harvest the coconuts which were divided up among the community or used for other agreed to purposes.

Christianity brought with it the observance of Sunday as a day of rest during which no work is done. This applies not only to work on the land, construction, or fishing, but also to food preparation which must be done the day before. A type of work schedule for Fridays and Saturdays geared to laborless Sunday has become customary. Thus, Friday is a day when women gather puraka, men and women gather and prepare coconuts. Saturday mornings appear to be reserved for community fishing expeditions that involve group participation, such as the fish drives. Foods are prepared by the women and cooked in pots or in covered pits for eating Sunday. Church services, picnicking and visiting or resting occupy Sunday. Religious services are not limited to Sundays. Every day just after sunrise and at dusk at least small groups of earnest Christians gather in the church for prayers and singing. Even out on the reef when community fishing drives have come to a conclusion, the fishermen pause for a moment while an elder or the pastor gives a prayer of thanks for the catch.

Emory indicated that certain forms of social segregation have been broken down with the advent of Christianity. No longer are women taboo in the community men's house. Women not only speak up in the general community council meetings, but are active leaders in church affairs, especially in the choir groups, and women lead in intoning hymns in church. The church activities appear to form a highly significant portion of the community's social activities. Membership in church and the Christian Endeavor also represents important prestige factors.

A more recent change in the social situation has come with the conversion of the son of Chief Tuiai and a number of other people totaling about 30 men, women and children to Catholicism. This has had an unfortunate divisive effect upon some aspects of community activities. For instance, all construction or repair work on buildings of a public or community nature formerly was a community undertaking directed by the chief and carried out by men designated by him with the concurrence of the adult men and women (the latter having to do with the provision of food for the working party). During the postwar period the small Catholic group decided to erect a chapel for services on the property of one of the converts. Chief Tuiai, as usual, designated a working party from the community to help erect the building and thatch the roof, However, the Catholic group was enjoined by the Spanish priest then on the atoll against accepting such help. The reason for this refusal appeared to be related to a desire to avoid having the Catholic group involved in the repair to the Protestant church which was scheduled for a subsequent occasion. By refusing the traditional community participation, the Spanish priest apparently felt that his converts would feel it easier to refuse their participation in the improvement and enlargement of the Protestant church to which he was opposed religiously.

This type of schism is unfortunate in any once tightly knit and smoothly functioning community, and on a small atoll such as Kapingamarangi, this is particularly deplorable. It was not ascertained whether this problem had as yet involved the question of use of the building materials on the community owned islets but such a question has within it potentialities of friction and conflict for the community.

Finally, the acquisition of both material objects and ideas from abroad especially during the postwar period is building up a certain amount of dissatisfaction among some young people with the restricted life and culture of the atoll. This dissatisfaction is evident particularly among the group of the "brighter" young men who have had opportunity to attend the Intermediate School at Ponape, some of whom even have had further training at the Pacific Islands Central School (PICS) at Truk, or at the Oa Mission School on Ponape. The attractions of the outside world of the high islands, limited as they are, have added to the urge created by population pressure on the atoll to move to Ponape to settle. The student group especially has acquired tastes and demands stimulated by what the young people have seen among or acquired from the foreign (i.e., American) administrative group on Ponape and Truk which involve expenditures that the atoll livelihood cannot support.

A difficult problem educationally is that education above the primary school level brings with it expectations of remunerative positions which generally are limited to a few teaching posts or a position as a medical aide. In the past, education on the atoll has been limited to the equivalent of the 6th grade level of grammar school in the vernacular. Two or three selected students per year have been brought to Ponape for further schooling, and further selection has brought a few individuals to Truk where they acquired the equivalent of the sophomore level in high school. Medical aides get experience in the Ponape hospital for a year or more. At this stage they are looking for positions. On the atoll itself, however, three teachers with such training and two medical aides are all that are needed or can be supported by the Kapinga people. Both because of cultural and language differences and because other areas supply their own trained personnel in the same fashion, there is virtually no remunerative outlet for excess trained personnel from Kapingamarangi.

CONCLUSIONS

1. Natural forces are building up and enlarging the land area above ordinary high tides at Kapingamarangi at a faster rate than they are eroding and destroying such surfaces. The process of land building generally is in a lagoonward direction, while land destruction generally is occurring on the seaward and the channel sides of islets.

2. The land surfaces above ordinary high tides have and are in process of slow migration. Along the eastern and southeastern sectors, this migration is lagoonward, while in the northeast sector of the reef the migration is partly lateral toward the west along the reef, although it is mainly lagoonward. This migration is related to the direction of the prevailing ocean winds and currents here modified somewhat by the situation of the individual islets on the reef. These movements lagoonward are the results of the accretion of sand and gravels derived from the outer edge of the reef and the reef flat, as well as from the erosion of the seaward and channel sides of the islets.

3. Additional land surfaces above ordinary high tides can be built up for planting to coconut and other vegetation by man's initiative at relatively rapid rates by the building of causeways across narrow inter-islet channels and by the piling up of rubble and coral boulders at selected locations on the reef behind which sand and gravels may accumulate through wave, tide and current action. Such land building processes should be actively encouraged in view of the population pressure. No significant ecological harm need be anticipated through the closing of the smaller inter-islet channels in the east central reef areas, since the wider channels in the northeast and southeast as well as the main ship passes in the south provide ingress for fresh ocean water. The western reef areas also offer potential land building sites.

4. Vegetation is highly man-manipulated, so that observable patterns are of little use in deducing "natural" biological processes or of soil conditions. A few valid generalizations may be made with respect to the zonation of certain vegetation types inward from the shores of the islets.

5. Since the entire land surface is generally in productive use, the increased planting of one type of useful tree must be at the expense of another type. Thus, coconut trees and breadfruit trees are in direct competition for space, while increased excavation of pits for puraka cultivation also means decreased tree space for coconut and breadfruit trees. An increase in pandanus palm leaf production for mat weaving also involves some sacrifice in food production.

6. Not all land owners keep their coconut land free of understory weed plants that compete for plant food and moisture. Plantation practices on other islands indicate that improvement in such practices would lead to higher coconut production.

7. There is a considerable crowding of coconut trees on the islets of Kapingamarangi. It is probable that more careful spacing of replacement plantings to give individual trees more room also would result in greater nut output, provided other competing growth also were limited or eliminated.

8. A large number of the coconut trees here appear to be too old for high nut yields. They need to be replaced gradually with young trees for realizing the maximum potentiality in nut production.

9. Growth of reef fish appears to be sufficiently rapid to keep up with present depletion rate through the fishing activities of the people on the atoll. However, according to Robert Harry, the expedition's ichthyologist, this growth is only rapid enough to maintain an ecological balance. The production of a large enough reef fish catch to make worthwhile the export of fish in refrigerated ships might readily result in the destruction of reproductive stock and a disastrous depletion of the fish food upon which the atoll people depend so heavily. On the other hand, tuna or bonito and other open sea fishes may furnish considerable unexploited resources for export or local use. Since these open sea fishes do not long survive being penned up in the coral rock pens such as are in use in Mokil, commercial exploitation of tuna or bonito would require modern fishing boats, equipment and preservation methods. The atoll people do not have the resources for providing such capital equipment and also would need to be trained for this sort of fishing.

10. Handicrafts in the way of woven Pandanus and coconut leaf mats, hats and basketry, canoe models and carved wooden bowls and platters, and trinkets made from seashells all provide possible commodities for sale outside the atoll were market outlets made available through organized commercial channels. No dependable income from such sources can be expected for the Kapingamarangi people, because of their isolation and the uncertain visits of ships to the atoll, as well as because of the difficulties of marketing at such great distances from the sources of the handicrafts.

11. Three types of unutilized energy sources are potentially available for use on the atoll which one day may become useful. Since there is almost vertical sunshine a large percentage of the time, the cheap solar stoves being developed for cooking purposes in some tropical or semitropical lands could be utilized effectively here. An almost constant easterly breeze of considerable briskness could furnish motive power to turn windmill driven electric generators

to provide light and power. Finally, the strong tidal current through the inter-islet channels furnish water-power potential for either direct mechanical conversion or through electrical power generation.

12. A fair degree of literacy seemed to prevail in the written use of the vernacular language among the younger generation, some of the young people in addition having acquired facility in the use of the Ponape language. This is in part the result of residence of several of them in Ponape and in part is the result of the use of the Bible and hymn book in church services for which no books in the native language exists. Six or seven of the young men and several of the young women also have learned enough English to act as interpreters. A few of the men also can speak a little Japanese. None of the atoll people here have had more than the equivalent of about the second year of high school education. On the other hand, further education does not provide equivalent job opportunities to those seeking them. The acculturation of the population to Western civilization has been proceeding rapidly with the travel back and forth of many of the atoll people to Ponape and back. Students attending school at Ponape and Truk return to pass on new ideas and tastes. Increased demands for numerous outside commodities has been accompanied by increased monetary income derived from the sale of *Pandanus* mats and copra. However, the demands or wants exceed the capacity of the atoll resources to purchase and acculturation thus has created some measure of dissatisfaction with the limitations of atoll livelihood among some of the young men. This dissatisfaction also extends in part to what is considered the "old-fashioned" ways of life. On the other hand, except for limited land available for homesteading at Ponape, opportunities for livelihood outside the atoll appears rarely. Efforts in the educational program should be directed toward increasing the appreciation of the students of the values of atoll life and toward improvements within the atoll sphere.

Appendix I

Rainfall data for Kapingamarangi

July - August
1954

Rainfall data was recorded from Weather Bureau rain gauges (copper tube type) placed upon four widely separated islets, Matukerekere Islet at the extreme southern end; Torongahai at the extreme northern end; in the middle of a large puraka patch near the middle of Hare Islet; and in the open church yard on Touhou Islet.

Readings were made once a week on the non-residential islets, but not necessarily at similar times of the day owing to travel time across the lagoon. On Touhou Islet, however, the gauge was read twice daily.

The following data give the weekly rainfall for the different islets read in inches of water. The dates indicate the reading date and the amounts are for the week preceding the date given.

Date	Torongahai	Touhou	Hare	Matukerekere
July 8	1.5	1.856	1.17	0.98
15	1.2	0.92	0.405	0.401
22	0.2	0.415	0.53	0.2
29	0.11	0.255	0.52	0.1
August 5	1.75	1.93	1.2	1.4
12	0.1	0.15	0.1	0.1
19	0.01	0.035	0.1	0.21
25*	1.0	0.46	0.26	0.24
Total for 8 weeks	5.87	6.021	4.285	3.631

*The rain gauges were removed for packing for departure on August 25, so that only six days' readings were taken. However, no rain was observed on the following day, so that this reading also may be taken as for a seven day period.

It is seen from the above that there are considerable variances in the amounts of rainfall on the different areas separated by distances of between 2 and 4 miles. There is no correlation with size of islets. The average for all gauges is 4.951 inches of rainfall which may be taken as the average amount for the atoll during the two months of July and August, 1954.

Appendix II

Meteorological data for Kapingamarangi

Prior to the arrival of the geographer who was responsible for the meteorological recordings after his arrival on July 3, other expedition members who had arrived earlier had set up the rain gauges on four different islets and attached a Taylor maximum-minimum thermometer to the shaded doorway of the thatched house used as a laboratory by the expedition. This was fixed approximately a meter from the ground. Maximum and minimum readings on June 25 were for the preceding 18 hours, thereafter for the preceding 24 hours. Taylor instrument readings were made by Niering from June 25 to July 10, accompanied by notes on rainfall occurrence.

Beginning with July 6, recordings were made on the Weather Bureau 10-day weather form. The maximum-minimum readings were made with standard Weather Bureau thermometers. However, on July 9 the maximum thermometer broke. Subsequent temperature recordings again were made by the Taylor instrument. On July 21, the Taylor instrument and the hygrothermograph were moved to a shelf under a tin roof of an open shack nearby where they were shaded and open to the breeze.

The following recordings and notes were made by Niering:

Date	Max. Temp.	Min. Temp.	Time	Remarks
June 25	87.5° F.	79.0° F.	7:50 a.m.	light breeze
26	90.5	79.5	8:00	" "
27	93.0	81.0	10:45	" "
28	94.0	81.0	8:00	" "
29	92.0	78.0	8:30	" " , shower, 6:30 p.m.
30	88.0	78.0	8:30	light breeze, intermittent rain p.m., evening
July 1	93.0	82.0	8:00	light shower 3 p.m.
2	92.0	79.0	9:00	light shower 4 p.m.
3	91.0	79.0	8:15	
4	92.0	79.0	8:45	
5	91.0	78.5	9:15	heavy showers 8 p.m.
6	89.0	76.0	8:40	
7	88.0	80.0	8:00	heavy showers p.m., night
8	91.0	78.0	8:15	
9	89.0	81.0	8:00	
10	91.0	82.0	8:15	

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Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- Twp. ---- Range----
Meridian 155E

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ----
Pres. Table ----

TIME USED (check one): PST | MST | CST | EST

Month JULY
Year 1954
Dates 5 To 15, incl.

Time ---- a. m.

Date	TEMPERATURE Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	WIND DIR. (from)	VELOCITY	STATE OF WEATHER	CLOUDS Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
5															
6	81.5	77.5	78.7	75.5			0	0	SC	5	L1	0	E		
7	83	81.2	82.5	76.5			E	2	SC	3	H8	E	E		
8	84	78	82	77			E	2	SC	4	L1	E	E		
9	83.8	81.1	82.5	77.5			E	1	C	1	L1	E	E		
10	83	81.5	83	76.5			E	2	SC	3	L2	E	E		
11	82	76	81.2	77			E	2	OC	9	L5	E	F		
12	81.5	78	82	78			E	1	SC	5	L1	E	G		
13	82	79	82.5	76.2			E	2	SC	2	L1	E	E		
14	84	78	80.5	76.5			E	1	OC	10	L5	E	G		
15	83	79	82.5	78			SE	2	SC	2	L1 H6	E	E		
Sums															
Means															

Time ---- m.

Date	TEMPERATURE DRY	WET	Dewpoint	REL. HUM.	WIND DIR. (from)	VELOCITY	STATE OF WEATHER	CLOUDS Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34

Time 7:30 p. m.

Date	TEMPERATURE Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	HYGRO. CHECK Temp.	Rel. Hum.	WIND DIR. (from)	VELOCITY	STATE OF WEATHER	CLOUDS Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
5	89	78	78	74.5			81.5	86	E	1-2	SC	9	L5	E	G		
6	85.5	77.5	82.5	76.5			84	72	E	0-1	C	0			E		
7	86.5	82	82.1	78			83	86	E	0-1	SC	9	L1	E	G		
8	91	82	83	78			84	70	E	0-1	C	0			E		
9	92	82	82	76.2			84	70	E	0-1	C	0			E		
10	85	79	81.5	77			83	78	E	1	C	8	H7	E	G		
11	85	79	81.5	77			83	75	E	2	OC	10	H7	E	G		
12	90	79	81.5	76.5			84	75	E	2	C	0			E		
13	92	81	83	77			86	70	E	2	SC	4	L4	E	E		
14	91	81	83	78.5			85	73	E	1	SC	1	L1	E	E		
15	90	81	82	77			84	79	E	1	SC	4	H6		E		
Sums																	
Means																	

Date	HUMIDITY Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	PRECIPITATION Kind	Time Began	Time Ended	AMOUNT ---- a. m.	---- p. m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	THUNDERSTORMS INTENSITY	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
5			E	C	R	5 PM	7:30PM	0.25	0.7	0.7			3								
6	90	65	E	C	0					0			0								
7	86	62	E	SC	R	2 PM	2:30PM	0	.09	.09			1								
8	94	62	E	C	R			.35	0	.35			0								
9	88	58	E	SC	0			0	0	0			1								
10	90	58	E	BC	R					.25			2								
11	94	66	SE	OC				.42		.42			1								
12	88	60	E	SC	R			.015	.15	.12			0								
13	78	54	E	C				0	0	0			1								
14	89	58.5	E	SC	R			.075	T	.075			0								
15	90	57.5	E	SC	R			.055	0	.055			0								
Sums					Number of days* .01"+	.10"+	.25"+	.50"+						No. thunderstorm days ----*							

REMARKS
41

The figures or letters used for cloud data are from the Cloud Code Chart of the Weather Bureau. The rain of 0.25 inches at 10 p.m. on July 5 was part of the shower that occurred in late afternoon.

Under Visibility: E means Excellent; G - Good; F - Fair; P - Poor.

July 9 - The maximum thermometer used up to this date was broken during this evening. Thereafter maximum and minimum readings were taken with a Taylor Maximum-Minimum Thermometer.

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section .... Twp. .... Range....
Meridian 155E

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ....
Pres. Table ....

TIME USED (check one): PST | MST | CST | EST

Month JULY
Year 1954
Dates 16 To 26, incl.

Time 7:30 a. m.

Date	Temperature: Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
16	84	81	82	77.5			E	2	C	1	H6	E	E		
17	84	79	82	77.5			E	2	C	1	LI	E	E		
18	83	81	83	77			E	3	SC	2	LI	E	E		
19	84	81	83	72			E	3	OC	9	LI	E	E		
20	84	81	83	77			E	3	SC	2	LI	E	E		
21			82.5	76.5			E	1	C						
22	84	78	82.5	75.5			E	1	SC	1-2	H1 LI	E	E		
23	84	82	82.5	75.2			E	2	SC		H6 L8	E	E		
24		81	82.9	76.5			E	3	SC	1	LI	E	E		
25	84	81	84	77			E	3	C	0	0	0	E		
26	83	81	83	75.2			E	3	C	5	LI	E	E		
Sums															
Means															

Time .... m.

Date	Temperature: DRY	WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34

Time 7:30 p. m.

Date	Temperature: Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Hygro. Check: Temp.	Rel. Hum.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
16	90	82	82	77.5			84	74	E	2	C	1	LI	E	E		
17	90	82	83	76.5			84	65	E	1	C	0			E		
18	89	81	83	77.5			85	74	E	2	C	1	LI	E	G		
19	92	81	83	77.5			85	74	E	2	C	0	0	0	E		
20	91	84	80	77			84.5	68	E	2	SC	2	LI	E	E		
21	89.5	82	82.7	75			84	69	E	3	C	0	0	0	E		
22	94	81	83	76			84	70	E	2	C	0	0	0	E		
23	92	81	83.5	76			84	69	E	2	C	0	0	0	E		
24	87	82	83.2	76.2			84	70	E	3	C	0	0	0	E		
25	87.8	81	83	77.5			84	78	E	3	C	0	0	0	E		
26	90	81.5	83.3	76.5			85	72	E	3	C	0	0	0	E		
Sums																	
Means																	

Date	Humidity: Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Time Began	Time Ended	Amount: .... a.m.	.... p.m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
16	86	62	E	SC				.08	.06	.14											
17	90	58	E	SC				.275	0	.275											
18	76	58	E	SC				0	0	0											
19	85	58	SE	SC				0	0	0											
20	80	53	E	SC				0	0	0											
21	75	60	E	BC				0	0	0											
22	85	58	E	C				0	0	0											
23	76	53	E	C				0	0	0											
24	74	60	E	C				0	0	0											
25	78	62	E	C				0	0	0											
26	74	57	E	C				0	0	0											
Sums					Number of days* .01"+ .10"+ .25"+ .50"+										No. thunderstorm days ....*						

REMARKS
41

The maximum-minimum readings for the p.m. of July 20 were from the hygrothermograph. At same time the maximum on Taylor instrument was 93, minimum was 80. Hygrothermograph also used on p.m. July 21 when Taylor instrument read 91 maximum, 81 minimum. The BC clouds on the 21st were high stratus, with low LI underneath.

After July 21 Taylor instrument was moved to the shed with Hygrothermograph where conditions appear to be more a reflection of natural conditions.

Data on July 25 a.m. was taken at 9 a.m. rather than usual 7:30 a.m.

Form 1009-E

(See instructions on cover)

Location: Kapingamarangi Eastern Carolines	Section ---- Twp. ---- Range---- Meridian ----	U. S. DEPARTMENT OF COMMERCE WEATHER BUREAU 10-Day Fire-Weather Record	Elevation (feet) ---- Pres. Table ----	TIME USED (check one) PST MST CST EST	Month JULY Year 1954 Dates 27 To 31, incl.

Time 7:30 a. m.

Date	Temperature Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Wind DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
27	83	81	82.5	77			E	3	SC	1	L1	E	E		
28	83	81	82.5	77			E	3	SC	1	M3	E	E		
29	82.2	78.2	82	77			E	3	C	0			E		
30	83	79	82	77			E	3	SC	1	L1	E	E		
31	82.5	77.9	82	77.8			E	3	OC	10	L8	E	F		
31															
Sums															
Means															

Time ---- m.

Date	Temperature DRY	WET	Dewpoint	REL. HUM.	Wind DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34

Time 7:30 p. m.

Date	Temperature Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Hygro. Check Temp.	Rel. Hum.	Wind DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
27	89	81	83.2	75.5			85	72	E	3	C	0			E		
28	89	80	81.8	78			85.5	84	E	2	SC	1	L1	E	G		
29	89	81	82.5	77.5			84	80	E	3	C				E		
30	93	81	83.2	77			83	76	E	2	C	5	L1	E	E		
31	86	78	82.5	75			84	68	E	3	OC	10	L5	E	F		

Date	Humidity Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation Kind	Time Began	Time Ended	Amount ---- a. m.	---- p. m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms Intensity	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
27	82	60	E	C				0	0	0											
28	84	62	E	SC		2:30		0	.245	245											
29	84	62	E	SC				.01	0	.01											
30	90	52	E	C				.04	0	.04											
31	94	68	E	OC				.7	T	.7											
31																					
Sums					Number of days* .01"+ .10"+ .25"+ .50"+									No. thunderstorm days ----*							

REMARKS
41

On July 30 rain from a totally overcast sky began about 8:30 p.m. and during most of the night the sky was overcast, continuing through the morning of July 31. Occluded weather continued through the afternoon and evening.

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- Twp. ---- Range----
Meridian ----------

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ----------
Pres. Table ------

TIME USED (check one): PST | MST | CST | EST

Month AUGUST
Year 1954
Dates 1 To 11, incl.

Time ---------- a. m.

Date	Temperature: Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
1	84	81	86	77.5			E	3	C			E			
2	83	81	82.8	72.8			E	3	SC	S	M3 LI	E	E		
3	83	81	82.8	77			E	2	C	5	LI	E	E		
4	84	75	78.5	76.5			E	1	OC	9	M3	E	G		
5	81	75.8	81.2	76			E	2	SC	3	LI	E	E		
6	83	81	82	74.6			E	3	SC	1	M3	E	E		
7	83	79	82	75.2			E	3	C	0			E		
8	84	80.5	84.5	78			E	2	SC	1	LI	E	E		
9	83	79	83	77			E	2	SC	2	LI	E	E		
10	83	80	81.8	75.8			E	3	SC	2	LI	E	E		
11	83	80	82	74			E	3	C	0	0		E		
Sums															
Means															

Time ---------- m.

Date	Temperature: DRY	WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
Sums													
Means													

Time ---------- p. m.

Date	Temperature: Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Hygro. Check: Temp.	Rel. Hum.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
1	87	82	83	76.5			85	72	E	3	C				E		
2	87	82	83.4	75.3			85	68	E	3	C				E		
3	90	81	83	76.5			85	70	E	1	SC	4	M3	E	E		
4	88	77	81	75.5			83	78	0	0	OC	8	M3	E	E		
5	86	80	82.8	76.8			84	72	E	3	C	5	LI	E	E		
6	86	81	83	76.3			84	73	E	3	C	2	LI	E	E		
7	86	82	82.8	76			84	72	E	3	SC	1	LI	E	E		
8	87	82	83.3	77.2			85	74	E	2	C	2	LI	E	E		
9	93	81	83	77.3			84.2	80	E	3	SC	2	LI	E	E		
10	86	80	82.8	77.8			84	78	E	3	SC	3	LI	E	E		
11	86	81	82	76			84	71	E	3	C	0	0	0	E		
Sums																	
Means																	

Date	Humidity: Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Time Began	Time Ended	Amount: ---- a. m.	---- p. m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
1	70	60	E	C				0	0	0											
2	78	61	E	SC				0	0	0											
3	82	54	E	SC				0	T	T											
4	90	61	NW	SC				.75	.44	1.19											
5	90	63	E	SC				0	0	0											
6	76	60	E	SC				0	0	0											
7	81	60	E	SC				0	0	0											
8	78	66	E	C				0	0	0											
9	86	59	E	SC				0	.15	.15											
10	81	61	E	SC				0	0	0											
11	81	59	E	SC				0	0	0											
Sums					Number of days*: .01"+	.10"+	.25"+	.50"+						No. thunderstorm days ------*							

REMARKS
41

August 1 temperature and other data were as of 11:20 a.m., one hour ahead of Australian time or one hour ahead of Guam time, when the Hygrothermograph needle indicated 10 p.m., so that the graph for this past week is in error. A new graph sheet is being inserted as of 11:30 a.m.

August 3, 9 p.m., - wind of Force 4 coming from SSE, light rain starting.

August 4, light surface winds during day from NW but rain clouds came from the east.

August 8 data was taken at 9 a.m. for the morning period.

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- Twp. ---- Range----
Meridian ----------------

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ----------
Pres. Table ------

TIME USED (check one): PST | MST | CST | EST

Month AUGUST
Year 1954
Dates 12 To 21, incl.

Time ---------- a. m.

Date	Temperature: Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
12	84	83	83	75.8			E	3	C	5	LI	E	E		
13	83	80.8	82.8	75.1			E	3	SC	1	LI	E	E		
14		79	82	74			E	2	SC	5	H6	NE	E		
15	82	76.8	78.5	73.5			O	O	SC	5	H6	N	E		
16	83	78	81	75			E	1	SC	3	LI	E	E		
17	82.5	78	82	76			E	2	C				E		
18	82.5	79	83	76			E	3	SC	1	LI	E	E		
19	83	79	83.2	76.2			E	3	SC	2	LI	E	E		
20	83	79	82.1	76.5			E	3	SC	1	LI	E	E		
21	83	81	82	76			E	3	SC	2	LI	E	E		
31															
Sums															
Means															

Time ---------- m.

Date	Temperature: DRY	WET	Dewpoint	REL. HUM.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
31													
Sums													
Means													

Time ---------- p. m.

Date	Temperature: Maximum	Minimum	DRY	WET	Dewpoint	REL. HUM.	Hygro. Check: Temp.	Rel. Hum.	Wind: DIR. (from)	VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Kind	DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
12	89	82	83	75			84	69	E	3	C	2	LI	E	E		
13	88	81	81.5	74			83	68	E	2	SC	7	H6	NE	E		
14	93	81	81	73.8			83.5	67		0	SC	8	H6	NE	E		
15	90	83	83	75			84.2	68	E	2	SC	3	M3		E		
16	90.5	80	82.5	75			84	69	E	2	C				E		
17	94	81	81	76			84	74	E	·2	SC	2	H6 M3	E	E		
18	87	81	82.3	74.5			83.7	71	E	2	C				E		
19	90	82	83	77			84.3	76	E	2	C				E		
20	92	81	82.5	76.2			84	77	E	3	C				E		
21	94	81	82.2	78			83	83	E	2	C				E		
31																	
Sums																	
Means																	

Date	Humidity: Highest	Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Time Began	Time Ended	Amount: ---- a. m.	---- p. m.	24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Time First Observed	Time Last Observed	Condition of Vegetation				
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39
12	76	57	E	C				0	0	0											
13	77	51	E	SC				0	0	0											
14	72	48	E	SC				0	0	0											
15	80	52	E	SC				0	0	0											
16	82	53	E	C				0	.005	.005											
17	85	54	E	SC				.02	0	.02											
18	81	61	E	C				0	0	0											
19	92	58	E	SC				.01	0	.01											
20	89	55	E	C				.07	0	.07											
21	87	55	E	SC				0	T	T											
31																					
Sums					Number of days*: .01"+	.10"+	.25"+ .50"+								No. thunderstorm days --------*						

REMARKS
41

Form 1009-E

(See instructions on cover)

Location:
Kapingamarangi
Eastern Carolines

Section ---- *Twp.* ---- *Range*----
Meridian ----

U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU
10-Day Fire-Weather Record

Elevation (feet) ----
Pres. Table ----

TIME USED (check one): PST | MST | CST | EST

Month AUGUST
Year 1954
Dates 22 *To* 23, *incl.*

Time ---- a. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	11	12	14	28	29	30	31	32	33
22	83	77	81.2	77			E	3	OC	9	L8	E	G		
23	82	80	82	76.3			E	3	SC	4	L1	E	E		
31															
Sums															
Means															

Time ---- m.

Date	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	3	4	5	6	11	12	14	28	29	30	31	32	34
22													
23													
31													
Sums													
Means													

Time ---- p. m.

Date	Temperature: Maximum	Temperature: Minimum	Temperature: DRY	Temperature: WET	Temperature: Dewpoint	REL. HUM.	Hygro. Check: Temp.	Hygro. Check: Rel. Hum.	Wind: DIR. (from)	Wind: VELOCITY	STATE OF WEATHER	Clouds: Amount (tenths)	Clouds: Kind	Clouds: DIR. (from)	Visibility	Percent Fuel Moisture	
Instr.	1	2	3	4	5	6	9	10	11	12	14	28	29	30	31	32	35
22	85	77	82.2	76.2			83.5	77	E	3	OC	10	L8	E	E		
23	86	81	82.5	76.5			84	75	E	3	C				E		
31																	
Sums																	
Means																	

Date	Humidity: Highest	Humidity: Lowest	Prevailing Wind Direction (day)	Character of Day	Precipitation: Kind	Precipitation: Time Began	Precipitation: Time Ended	Amount: ---- a. m.	Amount: ---- p. m.	Amount: 24 HR.	Snowfall	Snow Depth on Ground	No. Days Since Last Precipitation	Thunderstorms: INTENSITY	Thunderstorms: Time First Observed	Thunderstorms: Time Last Observed	Condition of Vegetation					REMARKS
Instr.	7	8	13	15	16	17	18	19	20	21	22	23	24	25	26	27	40	36	37	38	39	41
22	93	86.5	E	OC				.39	0	.39												
23	77	62	E	SC				T	0	T												
31																						
Sums					Number of days*: .01"+	.10"+	.25"+	.50"+						No. thunderstorm days ----*								

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ATOLL RESEARCH BULLETIN

No. 49

Bioecology of Kapingamarangi Atoll, Caroline Islands: Terrestrial aspects

by

William A. Niering

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Contents

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INTRODUCTION

The role of the land ecologist was to describe and to obtain a representative collection of the land biota. This was accompanied by observations and analyses of the interrelationships which exist between the plants and animals and their environment. Since man plays a dominant role in the environment, special emphasis was placed on human influences with respect to floristic utilization and vegetation management. It was anticipated that by this approach data would be obtained which would also be of value in guiding future administrative policies.

Kapingamarangi Atoll is located in the southern Caroline Islands 1° north of the equator (Fig. 1*). It is extremely isolated, the nearest atoll being Nukuoro 164 nautical miles northward. The pear-shaped atoll, approximately 5 by 6 miles in diameter comprises thirty-three islets all of which are located along the eastern reef (Fig. 3). The islets vary considerably in size. In length they range from 100 feet (Matukerekere) to one mile (Hare) while width ranges from 25 feet (Matukerekere) to 1200 feet (Werua). The total land area comprises approximately 276.4 acres or 0.42 square mile. The atoll is populated by 426 Polynesians (June 1954) who live primarily on two of the islets - Touhou and Werua. These as well as the outlying islets serve as their plantations.

Geologically the land area is composed of limestone bedrock, lime sands, and coarser coral and limestone fragments. On the ocean side the majority of the islets are formed of boulder conglomerate and/or coral rubble limestone which, except for occasional outcrops, is overlain with unconsolidated coral rubble and larger limestone fragments. Lagoonward the bedrock and rubble give way to beach sands. A few of the smaller islets located lagoonward on the reef are dominantly sand while others situated more oceanward are primarily limestone overlain with rubble and boulders. Two processes - erosion and deposition - play a major role in modifying the islets. Oceanward both processes are operative. Erosion occurs as undercutting especially along the channel margins. On the other hand as a result of deposition a beach ridge composed of rubble and boulders extends a few feet above sea level along the ocean and channel margins. Elevated reef rock areas frequently extend toward the ocean from the islets and probably represent remnants of a higher reef level that was possibly vegetated at one time. Dipping beach rock, apparently representing the former extension of the islet oceanward, is especially conspicuous on Torongahai. Lagoonward, depositional processes result in sandy beaches. Here sand bars commonly project from the ends of the islets. An exception occurs on Pumatahati where an extensive rubble beach extends inland for 50 feet. This may be correlated with severe storms in the past. In general, the islets are relatively flat with a rise of only a few feet above sea level. However, in the interior, banks of coral rubble reach a maximum of 14 feet above sea level as a result of puraka pit excavations. As a result of causeways constructed between the islets several have been completely connected. This accounts for the extensive length of Hare

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*All figures will be found at the end of the report.

islet. The formation of Pepeio, 0.7 acre, was initiated by man through his construction of a coral boulder wall on the reef flat. (Data in part from E. McKee, 1956.)

The soils are relatively immature and consist largely of mixtures of lime grove or rubble, sand, and fine lime particles combined with varying amounts of humus. Throughout most of the smaller islets and oceanward on the larger ones rubble soils are most common. Here the surface rubble is typically gray as a result of the presence of blue-green algae, primarily Entophysalis crustacea, in the surface layer. The organic layer varies considerably but reaches its greatest development in these rubble areas where it ranges from 6-12 inches in depth. In two areas, depths of 18 inches and 30 inches were recorded (Tokongo and Rikumanu, respectively). On Pumatahati a dark brown humus layer 6-8 inches in depth, free of the usual sand and rubble, overlies a highly phosphatic cemented layer. The organic material is also phosphatic (100% apatite, McKee, 1956) and acidic (pH 4.5). The consolidated layer underlying the humus consists of light brown cemented sand with scattered rubble. Lighter cream-colored particles are scattered throughout this brownish matrix. The upper zone is cemented giving way to soft crumbly material below. With the limited data obtained from these two layers the profile resembles that described by Fosberg (1954) as the Jemo soil series (see section on Associated fauna, birds). Lagoonward, sandy soils are most conspicuous, especially on the larger islets. In these soils incorporation of organic material ranges from less than 2 inches to 6 inches in depth. This is correlated with the lagoonward migration of the islets and the extreme immaturity of these soils as compared with the rubble areas. In the rubble and sandy soils only the A and C horizons are represented. A darker surface layer gives way to a grayish transitional zone which in turn gives way to the parent material composed of cream and orange foraminiferal sands and/or whitish rubble. Buried profiles which occur on several islets are indicative of previous storms. In the puraka pits a poorly drained muck type soil occurs (Stone 1951). On the smaller islets the soils would probably be classified in the stony and very stony complex while on the larger wider islets they appear similar to the Shioya or Arno types (Stone 1951).

On the atoll, fresh water occurs in the form of a shallow Ghyben-Herzberg lens. Although its distance above sea level was not determined, it may be assumed to be about 10-12 inches, as found in the Marshalls (Cox 1951; Arnow 1954). The upper limits of the water table vary considerably from the lagoon to the ocean side. On the larger islets of Werua and Taringa, it averages $2\frac{1}{2}$-4 feet from the surface near the center and lagoonward, while on the ocean side it varies from 5-$5\frac{1}{2}$ feet. On the smaller islets the water table is nearer the surface and the degree of salinity is higher. Oceanward on the larger islets, the salinity ranges from 1,000 ppm. to 3,800 ppm. and lagoonward from 18 ppm. to 340 ppm. (Table II). On the lagoonside, wells furnish fresh water for bathing and washing. Although this water is potable the natives prefer rain water which is collected in cisterns. On one of the smaller islets, Hukuniu, 0.9 acre in area, the salinity is similar to that of the ocean, averaging 18,000 ppm. Throughout, the soils and underlying bedrock have a considerable influence on the degree of salinity.

Climatic data for Kapingamarangi is limited to the Sailing Directions for the Pacific Islands, 1952 and observations made during previous and current expeditions. As would be anticipated, within this equatorial region the temperature is relatively uniform throughout the year. Data taken during July and August 1954 indicated the average maximum to be 89.1° F; the average 74° F. The average daily relative humidity was 57.4% with the average daily maximum reaching 83.8%. Available estimates on average yearly precipitation range from 78-108 inches. The Sailing Directions for the Pacific Islands, 1952 indicate the greatest rainfall during May and June and October and November (12 inches) and relatively light precipitation from February to April and from July to September (7 inches). The average for December to January is 9 inches. In 1954 there was little rain during July and August - the average for the seven week period was only 4 inches. Previous expeditions also encountered dry summers which extended into the "fall". Within a region dependent upon squalls, the rainfall pattern is probably very erratic. Droughts occur, the most severe of which extended from 1916 to 1918 and cost the lives of ninety natives. Although the Sailing Directions for the Pacific Islands, 1952 indicate winds from varying directions throughout the year, during July and August they were primarily from the east. Although the area is outside the typhoon belt, severe storms frequently occur, usually from the southwest. Information was available from the native secretary Rikaneti on the damage caused by these storms as far back as 1858. The most recent and severest was in 1947. Specific damage resulting from these storms will be included under the section on Climatic Influences.

METHODS

The small size of the atoll and proximity of the islets facilitated field studies.* During the first few weeks a general reconnaissance was made of all islets either by foot or native outrigger canoe. This was followed by more detailed corroborative studies on specific islets. It included collecting both flora and fauna, laying out strip transects across representative islets, studying the various environmental influences and talking with the natives concerning their land management practices, past and present, as they related to better understanding of the atoll complex. Joint studies were carried on with the expedition geographer (Herold Wiens) in mapping shoreline features and general vegetation maps.

Native interpreters aided in mapping the coconut and breadfruit-coconut plantations. This involved measuring from the high tide mark to the outer edge of the breadfruit canopy at 100 foot intervals around the islets. In order to estimate the number of coconut and breadfruit per acre, total tree counts were made on several of the smaller islets and quadrats 52 by 52 feet and 104 by 104 feet were laid out in the various plantations types on the larger islets. Soil and ground water data were obtained from wells and puraka pits with the team geologist (Edwin McKee). In conjunction with the marine biologists (Cadet Hand, Robert Harry and Jan Newhouse) the land vegetation was mapped as a part of a continuous transect extending from the seaward reef margin across an islet into the lagoon.

*Field work lasted from 22 June to 31 August 1954.

THE LAND BIOTA AND ASSOCIATED INFLUENCES

As a result of man's activities the entire land area is dominated by coconut (Cocos nucifera), breadfruit (Artocarpus altilis), pandanus (Pandanus tectorius) and puraka* (Cyrtosperma chamissonis). On the smaller islets coconut dominates completely. However, on the larger ones a typical zonation is evident (Figs. 10, 15, 30). Here the pure coconut plantations form an outer band and are replaced toward the interior by a mixture of breadfruit and coconut or pure breadfruit around the puraka pits. On the beach ridge a mixture of Guettarda speciosa and Scaevola sericea forms the outermost zone under the leaning coconut palms. The variety of vegetation types frequently encountered on atolls is absent (Fosberg 1953; Hatheway 1953). The typical strand vegetation, restricted primarily to the undergrowth and marginal areas, consists mainly of indigenous species.

As is typical of most atolls, Kapingamarangi is represented by a relatively sparse flora and fauna. Of the ninety-eight vascular plants found on the atoll it is estimated that thirty-eight are indigenous and fifty-eight introduced (Figs. 28, 29, 31). Of those introduced, sixteen are possibly of aboriginal origin (early introductions by man) and forty-two of more recent origin. Another category includes four species potentially indigenous but not found as mature specimens. These were found on the beach as drift seedlings. Since two species are considered to have more than one means of entry, the various categories, when totaled, slightly exceed the actual flora.

Since the total land area was sufficiently small a relatively complete floristic list was made for each islet (Figs. 28, 29). The number of species per islet varied from seven on the smallest islet (Matukerekere 0.03 acre) to sixty-one species on one of the larger inhabited islets (Werua). When the total number of species per islet is plotted logarithmically against islet size two linear relationships are evident (Fig. 32). Those islets less than 3.5 acres fall along one line with little variation in number of species. The other relationship includes those islets 3.5 acres and over and shows more strikingly the direct relationship between islet size and number of species.

Of the limited fauna, land and hermit crabs, insects, skinks, geckos, and birds are most abundant. The only mammal besides the pig and cat is a small rat which is locally abundant.

In order to adequately describe the land biota the vegetation has been arbitrarily divided into several types or areas: coconut plantations, breadfruit-coconut plantations including a breadfruit grove, puraka pits, marginal vegetation and inhabited areas. Since the faunistic aspects are generally similar throughout, a section on Associated Fauna follows the description of the vegetation. This is followed by sections on other environmental influences.

*Native name.

I Coconut plantations (Figs. 10-27)

Although coconut plantations dominate the smaller islets, on the larger ones they usually occur as marginal bands 100-150 feet in width oceanward and 60-100 feet lagoonward. According to the most recent survey of the Trust Territory these plantations occupy 320 of the 332.8 acres* of land area. This survey revealed by a reportedly actual count that there were 44,752 mature coconut and 22,213 immature coconut (Trust Territory Statistical Requirements, 1954). However, during the present survey it was found that only 157.03 acres are covered by coconut plantations. When the total number of trees is estimated in the coconut as well as breadfruit-coconut plantations only 22,174 coconut are present, i.e. about one-third the number previously reported (Wiens, Table III). It is obvious that the "320 acres" in plantations listed by the Trust Territory Statistical Requirements has not discriminated between coconut and breadfruit-coconut plantations. The validity of this lower figure (22,174) for the total number of coconut trees is accounted for by Wiens in calculating the tree density from close-up aerial photographs of other atolls and comparing them with Kapingamarangi. From these it is obvious that the estimated 116.5 coconut trees per acre on Kapingamarangi already represent overcrowding and that the census by the natives for the Ponape District Administration was much too high.

The plantations are dominated by relatively mature trees spaced on an average of 21 feet apart. Of course some variation occurs depending upon the age of the stand and the necessity to plant new trees in order to replace the older less productive ones. The most desirable plantation, according to Rikaneti, is planted so that the fronds merely touch to form a closed canopy. On Kapingamarangi there is considerable overlapping of the fronds, which would further substantiate the overcrowded aspect of the plantations.

The undergrowth varies considerably due to the recency of clearing, protective marginal vegetation, and islet size. On the smaller islets it is usually sparse or practically absent, while on the larger ones it has the potential of forming a continuous understory and dense ground cover. In general, Guettarda is most conspicuous on the smaller islets and gives way to Morinda citrifolia and Premna obtusifolia on the larger ones. Pandanus is common either as scattered mature trees or as immature localized stands. Numerous native varieties of it occur. Although seedlings are often abundant under some trees, most of them are propagated by burying the cut end of a branch from a known productive variety.

The shrub layer consists primarily of sprouts and suckers of Guettarda, Morinda, and Premna. Scaevola, although a common marginal shrub, is unimportant in the interior. Other shrubs contributing sporadic cover include Allophylus timorensis, Clerodendrum inerme and Pipturus argenteus.

On the smaller islets herbaceous cover may be absent or consist of scattered specimens of Asplenium nidus, Tacca leontopetaloides and Crinum sp.

*Wiens' mapped land surface indicates only 276.43 acres.

On the larger islets these species as well as Stenotaphrum micranthum, Thuarea involuta, Nephrolepis hirsutula, Wedelia biflora and others are most conspicuous.

Sharp lines of demarcation in the undergrowth are evident between recently cleared and uncleared areas. The ground is littered with coconut and pandanus leaf debris and occasional coconut logs. Coconut stumps, which are relatively common, are often covered with Leucophanes smaragdinum, a moss which forms cushion-like mats. Old stumps of Guettarda and Premna are also present.

Since considerable variation occurs within this type, depending upon islet size, the islets have been divided into three groups: islets 3.5 acres or less, islets 3.5-9.5 acres and islets over 9.5 acres (Fig. 31). The first category includes the smaller islets characterized for the most part by a Guettarda understory, a general uniformity in number of species and a sparsity of herbaceous cover. In the second and third categories the coconut plantations usually occur as a band surrounding the interior breadfruit-coconut type. Here the understory is primarily Premna and Morinda accompanied by an increase in herbaceous cover, especially grasses. The second and third categories are separated chiefly by the more mesophytic aspects of the latter. These variants closely resemble those described by Hatheway (1953) on Arno Atoll in the Marshalls.

A. Smaller islets (3.5 acres or less)

Most of the nineteen islets in this group are elongated in an ocean to lagoon direction across the reef. They vary in size from 25-350 feet in width and 100-500 feet in length. Due to the severe environmental conditions they support an extremely sparse flora comprising 5-16 species.

Coconut trees completely dominate these smaller islets and average 55-65 feet in height. On the immature sandy soils chlorotic palms are very conspicuous. For example, on Pepeio, a recently formed sandy islet, the trees, which are only 35-40 feet in height, are extremely yellow. According to the natives the trees are less productive on these islets than on the larger ones. Breadfruit is virtually absent: only one tree was observed.

The understory development varies considerably. In general, Guettarda is most characteristic with scattered Morinda and Premna. The former occurs as scattered trees 25-30 feet in height with various transitional stages, primarily stump sprouts or root suckers, as a result of continuous cutting in the past. Periodic clearing of the undergrowth leaves only occasional taller Guettarda and Pandanus scattered throughout the understory. In the interior lagoonward Scaevola occurs only sporadically although Rikumanu islet is an exception where it forms a continuous shrub layer. On two of the very narrow islets (Matuketuke and Matawhei), which are covered with coarse coral boulders seaward, the understory is practically wanting except for an occasional Pandanus. From the ocean margin these areas extend into the interior for 100 feet or more and give way to scattered low undergrowth lagoonward. In such areas lacking an understory old stumps indicate

previous vegetation which has either been cut during clearing operations or killed by salt spray or salt water inundation.

In general, the herbaceous cover is absent or comprises scattered specimens of Tacca, Asplenium, Crinum and Lepturus repens. Cassytha filiformis occurs as a parasite. Only on one islet, Turuaimu, which is extremely sandy and open, is herbaceous cover abundant. Here Triumfetta procumbens occurs as an important ground cover.

B. Intermediate islets (3.5-9.5 acres)

In contrast to the smaller islets, these seven tend to be more or less elongated parallel with the ocean and lagoon or along the reef. In size, they attain a maximum of 500 feet in width and 800 feet in length. A slightly more favorable environment exists and therefore a slightly larger number of species occurs. Although coconut plantations are dominant, on a few islets they give way to the breadfruit-coconut type.

On these islets the coconut are somewhat taller, ranging from 75-85 feet in height. Sprouted coconuts are usually not found in the plantations. However, on one islet, Pumatahati, they are relatively common. Since this is one of the two islets owned by the community it is apparently not managed as judicially as those privately owned.

The most striking change occurs in the understory. Although Guettarda still occurs as scattered trees Premna and Morinda, 5-7 inches in diameter or larger and 25-30 feet in height, predominate. In addition, Pisonia grandis is locally abundant, especially on Pumatahati, which was formerly covered by a Pisonia forest. Pandanus is scattered or localized. Sucker and sprout growth of Morinda and Premna often form a shrub layer 3-4 feet in height. Again land management practices account for the variation from a relatively open shrub layer with scattered larger Morinda and Premna to a relatively dense undergrowth.

Herb cover increases compared to that of the smaller islets. In addition to those species found on the smaller islets the two grasses Stenotaphrum and Thuarea are most frequent, especially in the openings. Other species which appear for the first time include Fimbristylis spathacea, Ipomoea littoralis and Ipomoea pes caprae.

C. Larger islets (over 9.5 acres)

These seven islets attain a maximum of one mile in length (Hare) and 1200 feet in width (Werua). Although the coconut plantations reach their maximum development on these larger islets the breadfruit-coconut type approaches, or may actually exceed, the area occupied by coconut. With the exception of bombed areas on two islets and causeways on Hare, the coconut form a relatively uniform closed canopy 85-95 feet in height. In the bombed sites on Hare the post-war trees are already productive, although they have not attained the height of the surrounding pre-war trees. This is especially

evident over a wide strip through the middle of the islet. In contrast, recovery has been considerably slower on Nunakita where scattered tall pre-war palms stand out conspicuously. This may also be correlated with greater disturbance and the abundance of bedrock outcrops.

As on the previous islets, Premna, Morinda and Pandanus are the typical understory species, although variants occur. Occasional associates include Pisonia and Hibiscus tiliaceus. Others such as Hernandia sonora, Cerbera manghas, Thespesia populnea and Ochrosia oppositifolia usually occur as scattered isolated trees. A small pure stand of Soulamea amara, 50 by 50 feet occurs on Nunakita. These trees are 6 inches in diameter or less and seedling reproduction is abundant. As on the smaller islets Premna and Morinda sprouts and suckers are common.

The herbaceous cover increases markedly compared to the smaller islets. Considerable variation also occurs especially between the wide and narrow islets. On the latter, such as Matiro, Hare, and Nunakita the two grasses Stenotaphrum and Thuarea, Wedelia, Vigna marina, and occasional ferns are most typical. On the wider more mesic islets, Ringutoru and Torongahai, ferns attain a lush development in the more shaded plantations with scattered grasses in the openings. The ferns Nephrolepis and Asplenium, form a continuous ground cover 2-3 feet in height. Further variation occurs from the ocean to lagoon side. Herbaceous cover is usually less continuous on the recently deposited sandy areas, in contrast to the highly organic rubble areas oceanward. In openings around abandoned house sites, now within the plantations, Vigna frequently forms dense tangles which completely engulf the other vegetation. The two most troublesome weeds are Wedelia and Vigna. Throughout, this pattern is modified periodically by complete clearing.

1. Sandy lobes

On the sandy lobes forming lagoonward a successional trend is evident in the understory. This is most striking as one progresses from the lagoon beach into the interior. On Ringutoru the lagoonward migration is so rapid that the typical marginal species - Guettarda, Scaevola and Messerschmidia argentea persist inland where they form an open sporadic understory. On these relatively unaltered sands the ground cover is sparse with only scattered patches of Lepturus and occasional seedlings and saplings of Morinda and Premna. At 100 feet or more from the margin this pioneer undergrowth gives way to a Premna-Morinda understory typical of the interior regions. Here Asplenium, Nephrolepis and Stenotaphrum form a continuous ground cover. These areas indicate a successional trend in the undergrowth from the early beach pioneers to a Premna-Morinda type.

2. Filled channels

These areas have formed as a result of deposition occurring between the islets to the point of connecting them. This accounts for the extreme length of Hare islet which actually consists of three islets that have been joined together in the past by severe storms (Fig. 23). The older

Rawa-Hare channel closed around 1865 and the more recent Herengaua around 1942. The former is clearly demarcated by the old inter-islet beach ridges which occur diagonally across the islet. The latter is delimited by the unaltered sandy soil and low yellowish palms. These areas are of particular interest in that they give some indication of the rate of organic accumulation and subsequent influence on the vegetation (see section on Biotic Influences). Just how soon coconut were planted on the older causeway is unknown. However, it may be assumed that planting occurred soon after it closed since the total land area of the atoll is so limited. On the more recent filled channel they were planted soon after its formation.

On the recently closed Herengaua channel the sandy soil shows no organic development. The larger palms 35-45 feet in height are just becoming productive while the smaller immature trees are extremely chlorotic. This area is in sharp contrast to the more recently bombed and replanted areas on Hare where the trees are already taller, more vigorous and more productive. In the sparsely developed understory scattered stump sprouts of Guettarda, Scaevola and Messerschmidia occur. Herbaceous cover is wanting. Morinda and Premna seedlings are rare and the trend toward such an understory is not as yet evident.

On the older channel a layer of dark organic matter 1 inch in depth has developed. It is intermixed with grass roots and gives way to a 6 inch layer of gray stained foraminiferal sands which in turn give way to unaltered parent material. The vegetation differs considerably from the surrounding areas. Coconut dominates across the entire channel in contrast to breadfruit-coconut plantations on both sides of the channel. The understory, where present, is dominated by Guettarda which occurs either as sporadic trees or stump sprouts. Large shrub clumps of Scaevola which have been cut many times also occur. Grasses such as Stenotaphrum, Lepturus and others form a continuous ground cover. Some areas are extremely savanna-like, i.e. relatively open with scattered palms and grasses. Asplenium occurs only locally. In the adjacent areas on either side of the causeway Morinda, Premna and Pandanus dominate and form a dense understory. Here Asplenium is more common with grasses forming a less continuous aspect. In contrast to the sandy lobes, there is little evidence of vegetational change even on this older filled channel.

On the coarse coral boulders of the relict beach ridges crossing the islets, Guettarda forms a conspicuous band along with Asplenium. One of the tall leaning coconut palms on the ridge, which is highly scarred by innumerable knife cuts, was said to have been planted when the causeway closed.

II Breadfruit-coconut plantations (Figs. 10, 11, 15-18, 20-23)

On thirteen of the larger islets coconut plantations give way in the interior to a mixture of coconut and breadfruit occurring on, but also beyond, the rubble banks surrounding the puraka pits. From the lagoon the breadfruit stand out conspicuously with their dark green canopies which tower 15-20 feet above the coconut. This type extends to within 100-150 feet of the high tide

mark on the ocean side and 60-100 feet on the lagoon side. An exception occurs on Touhou islet where this admixture dominates the entire islet and occurs to within 35-45 feet of the ocean shore and 12-25 feet of the lagoon shore (see section on Inhabited Areas). On the smaller islets only a few scattered breadfruit occur while on the larger ones the breadfruit-coconut type may equal, or exceed, the area occupied by coconut plantations. It reaches its maximum development from the center of the larger islets lagoonward. Oceanward the breadfruit decreases in abundance until only scattered recently planted small trees demarcate this type from the pure coconut. This restriction to the larger islets is apparently correlated with the greater protection afforded from adverse saline effects.

The presence of breadfruit in this type contributes to a more dense and mesophytic aspect. The breadfruit occur fifty or more feet apart interspersed with coconut and together they form a relatively closed canopy. Although there are fewer breadfruit than coconut the large crowns of the former contribute considerably greater cover. The trunks average 2-3 feet in diameter although occasional trees reach 6 feet in diameter and often attain a height of 90-100 feet or over. The straight fluted trunks are usually devoid of branches for the first 25 feet or more. In some areas the recent planting of breadfruit in the coconut type is evident by the generally smaller trees, 8-12 inches in diameter. Openings that occur in the canopy are due primarily to dead or partly defoliated branches as a result of storms. On two islets, Hukuhenua and Ringutoru, damaged trees are especially common. In the upper canopy large branches are frequently devoid of leaves or the foliage is dwarfed. These branches are the favorite nesting site of the gregarious white-capped tern (see section on Associated Fauna). Under the breadfruit, seedling reproduction is evident only on Hare islet. Here the seedlings are often nipped off, probably by hermit crabs.

The understory varies considerably from the rubble banks to the area beyond. On the banks the recency of excavation results in diverse patterns. On those more recently disturbed, *Thuarea*, and occasionally *Lepturus*, are typical pioneers. These species, especially the latter, are important in stabilizing the sloughing of the banks caused by crab activity.

On the older more stable banks *Pandanus* plantings are common. The trees are spaced 3-5 feet apart and range from 6-12 feet in height. Their generally small and uniform size suggests post-war planting, probably resulting from the recent demand for mats and other handicrafts. Since they provide an important source of leaves used in mat making, many of the lower ones have already been cut off close to the stem. Shrubby undergrowth includes thickets of *Clerodendrum* and sprouts and suckers of *Morinda* and *Premna*. Scattered *Hibiscus tiliaceus* frequently lean out over the puraka pits. In the more shaded areas *Thuarea* and *Stenotaphrum* form continuous carpet-like patches over the rubble. They are occasionally intermixed but more commonly occur as pure grassy areas. On the more open banks *Vigna* and *Wedelia* sometimes form a continuous cover 1-2 feet in height.

Beyond the banks the undergrowth pattern is quite similar to that found in the coconut plantations on the larger islets, except for a less profuse

growth due to the dense shade produced by the breadfruit. Variation in this pattern occurs on Ringutoru where a small area 100 by 150 feet is planted to banana (Musa sapientum) and papaya (Carica papaya). Although some bananas are produced, they are considered a luxury. In contrast, few of the papaya trees appeared very productive.

On Werua, the widest islet, this mixed type gives way to a relatively large area dominated exclusively by breadfruit which occurs on the rubble banks surrounding the puraka patches (Fig. 15). These trees are occasionally larger in diameter and form a denser canopy. The paucity of trees in the smaller size classes is similar to that reported from the Marshalls (Hatheway 1953). The undergrowth here is similar to that found in the breadfruit-coconut plantations but is less dense. In the openings extensive pandanus plantings occur.

Within the plantations there are several kinds of breadfruit: the Kapinga type, probably an aboriginal introduction, and those of more recent origin: the Nukuoro, which was originally introduced from Samoa circa 1922 and the Ponape brought in circa 1935. Although opinion varies as to which fruit is best, the Kapinga type is apparently preferred and dominant throughout the plantations. This is followed by Nukuoro and Ponape types in preference and abundance. The Kapinga and Nukuoro varieties are propagated by seed and the seedless Ponape trees by air grafting and suckers. According to the natives, all trees are productive two to four times per year depending upon rainfall.

Although they report that there was more breadfruit in the past, today there is little evidence of this. On the contrary, the lack of old stumps in the breadfruit-coconut type is suggestive of relatively recent expansion of this type into areas formerly dominated by pure coconut. Today the presence of young trees in the marginal areas is also indicative that the mixed plantations are still increasing in area. On the other hand, in the pure breadfruit grove, the large cut stumps would suggest that this area has probably been producing breadfruit longer than any other area on the atoll.

III Puraka pits (Figs. 10, 11, 13, 15, 17, 18, 20-24, 30)

Puraka pits occur on eleven of the larger islets. They are located near the center or slightly lagoonward and are surrounded by breadfruit and coconut. The pits, which vary in size from a few square feet to one extensive area of eleven acres on Werua, are formed by excavating the rubble to slightly below the fresh water level and then adding organic matter in which puraka (Cyrtosperma chamissonis) is subsequently planted. A muck type soil eventually develops, the upper 6 inches of which consist of a fibrous network of roots with an algal covering over the surface layer. Since this soil is usually saturated, narrow elevated paths traverse the pits. Although the banks are generally 3-5 feet in height above the floors of the pits larger ones on Werua attain a height of 10-15 feet or more.

The puraka is planted 8-12 inches apart and varies in height from 2-6 feet or over, depending upon the stage of maturity and light intensity. In

the more shaded situations the plants are taller and more vigorous. Those in the center of the larger patches are frequently smaller and the leaves are yellowish-brown, which may be caused by the intense insolation. According to Lia, one of the native women, the marginal areas are most productive. This would suggest that intermediate light intensity is most favorable.

Banana (_Musa_ sp.) and ornamental hibiscus (_Hibiscus_ sp.) are scattered throughout the patches. _Cassia alata_, a recently introduced shrub, used for medicinal purposes, is rare. In a few of the older patches rows of _Premna_, 6-8 inches in diameter, still persist and demarcate previous property boundaries.

The most abundant and troublesome weed is _Jussiaea suffruticosa_ which grows 2-3 feet in height. Other herbs occasionally found include _Angelonia angustifolia_, _Lindernia antipoda_, _Ipomoea littoralis_, _Cyperus brevifolius_, _Hedychium coronarium_, and _Fimbristylis miliacea_. Along the paths one finds _Alternanthera sessilis_, _Digitaria microbachne_ and _Paspalum vaginatum_.

Puraka is planted, cultivated, and harvested by the native women. Weeding of the above species, especially _Jussiaea_, is one of the major jobs. Periodic mulching involves adding banana and breadfruit leaves.

Only one small abandoned pit was noted where the natives indicated that they were unable to grow puraka. Since the water was slightly saline to the taste this may account for their failure.

Over the years the number of puraka pits has increased with the increase in population and in several areas expansion is still under way. One landowner killed a large breadfruit by fire in order to enlarge his puraka holdings. Although _Cyrtosperma_ is most common now, taro (_Colocasia esculenta_) was dominant in the past. Apparently the more vigorous drought-resistant puraka crowded out the less successful taro. Today the latter occurs only as scattered isolated specimens.

IV Marginal vegetation

The marginal vegetation includes a relatively conspicuous border beneath the leaning coconut (Fig. 33). It is best developed on the oceanward and inter-islet beach ridges. Lagoonward the border is interrupted by native structures and finally gives way to sand bars at the ends of the islets.

Along these marginal areas two geological processes are operative: seaward, severe erosion and deposition and lagoonward, primarily deposition. As a result of the differential influences of these factors diverse patterns result. Therefore the discussion will be divided into Oceanward and Lagoonward aspects.

A. Oceanward

Tall leaning palms are typical along the beach ridge. They are generally planted to within a few meters of the edge and with subsequent

erosion mature trees are found growing at the high tide mark. Under these palms, Guettarda and Scaevola form a two layered border on the beach ridge. The former occurs either as low trees, 12-15 inches in diameter and 18-25 feet in height, or as numerous stump sprouts of varying size. The latter grows in front of or under the Guettarda as a narrow often discontinuous shrub layer 5-12 feet in height. The width of the band varies from 15-30 feet with the Guettarda canopy projecting 15-20 feet out over the water. These species occur either together or in nearly pure stands depending upon the prevailing winds and erosion. Scaevola tends to increase in importance where erosion is least severe while Guettarda is common in the more severely eroded sectors.

On the seaward points of the smaller islets, where raised reef rock extends oceanward beyond the high tide mark, small thickets of Scaevola backed by Guettarda are extremely characteristic. The persistence of the former here is apparently correlated with the protection afforded by the reef rock. On the larger islets the pattern is more heterogeneous, but again dependent upon the severity of erosion and deposition.

Along the inter-islet channels, where erosion is most severe, a striking pattern is evident between the windward and leeward sides. On the east-southeast windward sides Guettarda is dominant and forms a continuous border. On the slightly more protected leeward margins the two species nearly share dominance. Where Scaevola occurs in abundance on the windward side there is usually some protection such as raised reef rock or beach rock off shore. Even fish traps constructed in the channels serve to lessen erosion.

In addition to Guettarda and Scaevola, several other marginal species are represented. According to their relative importance they include Pandanus tectorius, Messerschmidia argentea, Cordia subcordata, Terminalia samoensis, Clerodendrum inerme, and Barringtonia asiatica.

On some of the smaller islets such as Matuketuke and Matawhei the marginal vegetation is completely absent except for coconut and sporadic Pandanus. This may be a result of salt spray, erosion, cutting or a combination of these factors.

The effects of marginal erosion and salt spray are most striking along the windward sides. Here root systems are often partially or almost completely exposed. Coconut palms are sometimes eroded out and their trunks found strewn on the beach. Clumps of Scaevola are also washed away. Probably the paucity of this species in these areas is correlated with its less extensive more shallow root system compared to that of Guettarda. Of these marginal species Guettarda, Cordia, and Terminalia are most conspicuously affected by salt spray (see section on Climatic Influences).

Some of the natives apparently recognize the protection afforded by this marginal band in the interception of salt spray and islet stability. Others, however, cut or burn the old Guettarda if they no longer produce wood useful in construction.

B. Lagoonward

Although leaning coconut are characteristic along the lagoon shore, the understory is often less continuous, especially where houses or other native structures occur. Pandanus is commonly associated with Scaevola and Guettarda. On the larger islets large trees of Calophyllum inophyllum 12-24 inches in diameter lean out over the lagoon. Their restriction to the lagoon shore is unique. Only two trees were found elsewhere: one seaward severely damaged by salt spray and another in the interior in excellent condition. Although seedlings occur on the beach, most of these trees are planted.

At the ends of the islets sand bars project lagoonward. Some are ephemeral with little or no vegetation while others are covered with scattered clumps of Scaevola and Messerschmidia as pioneers. Within this low shrubby matrix young coconut are planted by the natives. In other areas, where the advance of pioneers keeps pace with the accumulation of sand, a step-like band of Scaevola results. Here rows of Scaevola seedlings on the back shore give way to Scaevola 3-6 feet in height which are backed by a taller band 9-12 feet in height. Guettarda forms a tree layer beyond.

As the islets migrate lagoonward Guettarda and Scaevola persist inland. Large Guettarda occur scattered under the coconut or sometimes on former beach ridges left behind as the islets built lagoonward. Some appear to be quite old and others have been cut many times and resprouted. If these are relicts of the earlier pioneers, the building processes are taking place extremely rapidly. On Ringutoru the rate of migration was estimated from data furnished by the natives regarding the position of former marginal trees. In this area the cove sector of the beach between the sand bars is building at the rate of 1 foot per year. From the vegetational pattern, the adjacent sand bars are probably building even faster.

All along the lagoon beach, drift seedlings are common. On the back shore detailed observations were made on seven islets regarding the frequency and abundance of seedlings. The list which follows includes the most important species arranged according to their relative abundance.

Scaevola sericea
Guettarda speciosa
Pandanus tectorius
Messerschmidia argentea
Barringtonia asiatica
Hibiscus tiliaceus
Morinda citrifolia
Calophyllum inophyllum
Premna obtusifolia
Hernandia sonora

The first six species occurred on over two-thirds of the islets studied. Although saplings of Barringtonia asiatica were present on all

islets analyzed only one mature tree was found. Apparently the severe insect and crab damage prevents more trees from attaining maturity. On the beach four new species of drift origin, not presently represented in the flora as mature specimens, were found. These included Mucuna gigantea, Intsia bijuga, Barringtonia racemosa and Kleinhovia hospita.

In addition to the numerous tree seedlings, herbaceous cover is also abundant in some areas along the beach. On several islets Vigna is the dominant pioneer and commonly forms dense tangles over the adjacent marginal species. This species often attains such deneness that trees such as Pandanus must be periodically cleared of it. Other herbs frequently found include Ipomoea pes caprae and Triumfetta procumbens.

On Pumatahati, in contrast to the typical sandy beaches, the lagoon beach is formed of coral rubble. Here Cordia 35 feet high forms a border 50 feet in width. The trees exhibit a poor growth form as a result of cutting and possible disturbance by storms in the past. Herbaceous cover is wanting.

V Inhabited areas

The majority of the 426 natives live on Touhou and Werua. On the former the entire area is inhabited while on the latter only the lagoon and inter-islet shore areas are populated. A few families live on the outlying islets. Throughout the villages coconut or an admixture of breadfruit and coconut predominate. In addition to the regular coconut two recently introduced varieties are represented: the so-called "red coconut" with a distinctive reddish fruit, and a dwarfed type which is productive when 10-12 feet in height. As previously mentioned, the breadfruit canopy on Touhou extends closer to the beach than on any other islet. It occurs on an average of 30-50 feet from the high tide mark but at one point comes to within 12 feet of the water. The occurrence of breadfruit so close to the margins may be correlated with the considerable elevation of the islet above sea level - maximum 12 feet - in contrast to the others. According to the natives this topography has resulted from the accumulation of rubble and sand from former cooking sites. As on other islets, occasional branches of the breadfruit are killed back, especially those facing the prevailing easterlies. One of the largest breadfruit on the atoll is found along the village street on Werua. It is 77 inches in diameter and 115 feet in height.

The undergrowth is characterized by an abundance of Pandanus and recently introduced species. Even on Touhou where the native houses are closely spaced, each family owns sufficient land to support several Pandanus which supply a readily available source of food. Other understory species include Morinda, Pisonia, Premna, and Guettarda. The leaves of Pisonia were formerly mixed with taro in cooking. However, the sparsity of this species (taro) no longer necessitates planting Pisonia and it is therefore not as common in the village areas as previously. Banana and papaya are scattered throughout the villages although productive specimens are rare. Recently introduced ornamentals include Codiaeum variegatum, Plumeria rubra, Zephyranthes rosea, Polyscias scutellaria, Polyscias fruticosa, Crinum sp. and Hibiscus sp. (hybrids). Plumeria is highly valued for its flower which is used in making

leis. These ornamentals are especially conspicuous around the cemeteries. The shrub Polyscias scutellaria is commonly used as a border along the streets and to demarcate property lines.

Although the natives weed and clean up fallen leaf debris a few scattered introduced weeds persist among the gray coral rubble. These include Adenostemma lavenia, Eclipta alba, Phyllanthus niruri, Portulaca oleracea and Hemigraphis reptans as well as scattered patches of grasses and sedges. On the bare rubble Premna and Morinda seedlings are especially abundant under Pandanus and other trees which are visited by starlings. However, there is little evidence that these seedlings survive. Around a few of the houses small nurseries of breadfruit, Calophyllum, and recently introduced species are encountered. Seedlings of drift origin such as Calophyllum are protected in these nurseries until moved to the plantations.

VI Associated fauna and related influences

Since the determination of certain groups is incomplete at this writing general common names are used in certain sections. The ecological role contributed by the more important group follows.

A. Annelids (Earthworms)

Earthworms (Pheretima upoluensis, P. bicincta, Dichogaster sp.) though not common, are locally abundant wherever there is considerable moisture and organic matter in the process of decomposition. In the plantations they are found in the moist humus under piles of decaying coconut husks. In one such area 101 specimens were collected in a sample plot $\frac{1}{2}$ by $\frac{1}{2}$ meter and 15 cm. in depth which had been treated with mercuric chloride. They were also found under old logs, fern clumps, and piles of plant debris. Their influence is apparently localized in areas of high organic content.

Dr. G. E. Gates who determined the annelids reports one new species. Its origin is puzzling but "...it must be somewhere in Southeast Asia or the Malaysian islands including New Guinea."

B. Crustaceans (Land, Hermit and Coconut Crabs)

In the plantations, the most abundant forms of animal life are the land crabs (Cardisoma rotundum, Gecarcoidea lalandei) and hermit crabs (Coenobita brevimanus, C. perlatus). Other land crabs of lesser importance include: Metasesarma aubryi, Sesarma rotundatum, Geograpsus crinipes and G. grayi. These crabs play a major role in the incorporation of organic matter into the soil and their numerous burrows aid in soil aeration as well as in increased porosity. They are found on all islets but are most abundant on the larger ones. The land crabs occur either above or below the ground. Above ground they are characteristically found in association with hermit crabs under old piles of coconut husks scattered throughout the plantations. The pandanus prop roots, as well as the buttressing breadfruit bases, also afford excellent cover. In the scattered bedrock areas innumerable holes,

resulting from the weathering of the porous limestone, offer a natural habitat. Here coconut crabs (*Birgus latro*) are also found. In the sandy or loosely consolidated rubble soils, land crabs dig burrows at least 18 inches in depth. Areas were observed in the loose rubble where up to fifteen holes occurred within a 10 by 10 foot area. The banks surrounding the puraka pits are undermined with holes which occur in a layer-like fashion among the breadfruit roots. The amount of constant sloughing of the banks indicates considerable activity. The crabs, except for the smaller hermits, are usually not readily observed during the day save in the more moist and shaded situations.

In a strip transect on Torongahai involving fifteen 52 by 52 foot quadrats the crab population was studied by actual count of those found under coconut husks, old logs and other debris as well as the number of holes (Fig. 30). A total of 316 hermit, 205 land and 5 coconut crabs was found in the 40,560 square foot area. The maximum number recorded for a single quadrat was 72 hermit and 38 land crabs. This quadrat occurred under the largest and oldest coconut where the rubble was extremely compact. In contrast, the largest number of holes occurred in the sandy or loose rubble areas. Although the number of piles of coconut husks per quadrat varied, thus modifying the data, certain trends are evident when the number of burrows and number of crabs are plotted. The maximum number of crabs was observed in the compact rubble where they were utilizing the piles of coconut husks for cover. In contrast, on the adjacent loose rubble banks and in the sandy areas lagoonward burrows were very numerous but actual numbers of crabs observed were generally low. One exception occurs 200 feet in from the lagoon, but here the high population apparently correlates with a greater number of piles of coconut husks. The absence of crabs in certain areas appears to be compensated by an increase in burrows which suggests that the population may be comparable in the different sites but not evident because of the different habitats they utilize in the different areas.

Smaller hermit crabs were numerous, especially near the beach. Recently fallen or discarded *Pandanus* keys and exposed coconut meat were rapidly covered with hordes of these small crabs. Few coconuts were available for them but occasional opened ones were observed. The larger hermits probably open the nut after which both large and small forms eat the meat. In order to have coconuts for planting the natives either tie mature nuts on branches above the ground or lay them on their roof tops until good sized sprouts are formed. They are apparently unharmed by the crabs after they have germinated to this point. These small crabs were also observed chewing the tips of the twigs of *Barringtonia asiatica* and petioles of *Guettarda* were also damaged. Terminal portions of seedlings of breadfruit, *Calophyllum* and *Hibiscus tiliaceus* were nipped off, probably by crabs. Although not observed feeding they were found on low *Premna* sprouts.

Land crab and larger hermit crab activity began at twilight and continued into the night. Nocturnal observations revealed numerous crabs either pulling breadfruit leaves into their burrows or actually feeding on them. Although breadfruit leaves appeared to be the preferred food other

materials found in their burrows included coconut husks, twigs, and *Pandanus* leaves. One whitish intermediate sized species was observed with a dead gecko.

The coconut crab, found either in the cavernous bedrock areas, puraka banks, or large hollow breadfruit trees, is the only land crustacean utilized by the natives for food. Because they are primarily nocturnal, they are hunted at night with lights. The pressure on this delicacy keeps the population at a minimum.

C. Insects and arachnids

Although insects are common there are no major pests. In the plantations orthopterans (primarily grasshoppers), lepidopterans and hemipterans (leafhoppers) are abundant in the *Stenotaphrum* and *Thuarea* grass cover. In the more open areas a larger lepidopteran (butterfly) is relatively common. Over the puraka pits dragon flies are characteristically found apparently feeding on smaller insects. Under piles of coconut husks and other debris ants, earwigs, cockroaches, scorpions, spiders, and sowbugs (Crustacea) are numerous. Two species of the Phasmidae, seldom seen by the natives, were collected from the understory vegetation. In the bombed areas, craters and old cisterns accumulate stagnant water which provides excellent breeding sites for the mosquito. These areas could be readily controlled by an application of oil.

Certain trees and shrubs show considerable insect damage. The leaves of *Scaevola* are frequently attacked by a leaf miner. New shoots and buds of *Calophyllum* and *Barringtonia asiatica* are often infested to the point of disrupting the normal growth pattern, especially in the latter. The scalloped foliage of *Premna* and other species is indicative of leaf feeding or cutting forms. The smaller *Pandanus* trees are sometimes parasitized by mealy bugs to the point that they are cut and burned.

The flying insects are probably of primary importance in the pollination of most species. However, on *Guettarda* ants apparently play a similar role in the process of feeding on the sweet nectar.

In the inhabited areas insects were uncommon during the day except where marine specimens were drying or fish were being handled. Around such material dipterans (common flies) were abundant. In the plantations they are sometimes a troublesome pest, especially on the lee sides of the islets. In the evening lepidopterans (small moths) and coleopterans were relatively common around the lights. Ectoparasites were found on birds and rats as well as on the natives.

D. Reptiles (Skinks and Geckos)

Skinks and geckos are the only reptilian forms on the atoll. Of these the skinks are more abundant and occur on all islets. They are seen almost everywhere rapidly scampering over the fallen leaf debris in the

plantations. Their abundance is probably correlated with the lack of predators. Although they are primarily insectivorous in habit, earthworms and smaller geckos occasionally become their prey. Geckos, although found on the smaller islets, are most numerous on the larger ones. The larger species is usually found on the coconut trunks or in the axils of the fronds. The small form, although found in the plantations, is most commonly seen in the native houses.

E. Birds

The avifauna comprises permanent residents, migrants, and occasional visitors. Of the former, the Micronesian starling (Aplonis apacus), reef heron (Demigretta sacra sacra), noddy tern (Anous stolidus pileatus), white tern (Gygis alba candida), and white-capped tern (Anous minutus marcusi) nest in the plantations. According to the natives the frigate bird (Fregata sp.) does not nest but merely roosts on Tirakaume islet. A domestic variety of the introduced fowl (Gallus gallus) occasionally escapes from captivity and also seeks refuge in the surrounding plantations. The New Zealand cuckoo (Urodynamis taitensis), a migrant, was observed several times gliding secretively through the breadfruit-coconut canopy. Along the shore, migrants such as the whimbrel (Numenius phaeopus), plover (Pluvialis dominica fulva), and turnstone (Arenaria interpres interpres) are common feeding on the marine life. The black-naped tern (Sterna sumatrana sumatrana) is relatively common and, according to the natives, nests on the elevated reef rock. Two visitors, the brown booby (Sula leucogaster plotus) and crested tern (Thalasseus bergii pelecanoides) were seen only once during the two months.

Those birds found nesting in coconut or Pandanus include starlings, reef herons, noddy and white terns. In contrast, the white-capped terns nest exclusively in the large breadfruit trees. Of these birds only the starlings feed on land. Their main sources of food comprise the fruit of Premna, Morinda, and breadfruit. A preference for the latter has made it necessary to pick the fruit while still immature. In contrast, the main diet of the noddy, white-capped, and white terns is fish. Large flocks are often seen feeding in the lagoon, especially around the coral mesas. The solitary reef heron wades the outer and inter-islet reef areas at low tide feeding on the various marine forms.

The gregarious nesting habit of the white-capped tern may have considerable influence on the breadfruit. The natives report that these birds have actually killed their trees in the past. In one 90 feet in height and 2 feet in diameter eighty nests were estimated, all of which were concentrated in the upper 30 feet of the crown. On one branch 6 inches in diameter and 15 feet in length, twelve nests 1-2 feet apart were recorded. Where the nests are this abundant at least 75% of the branches are white with fecal matter. Below these nests no branches occur. Previously existing branches were probably severely injured or killed as a result of the birds, thus necessitating removal.

The role played by these birds presents a real dilemma. Do they prefer those branches partially defoliated, possibly by salt spray or ground

water salinity, or has this condition resulted solely from the activities of the birds? Although these terns are occasionally found nesting in the outer branches of denser more vigorous breadfruit, the concentrated populations are most conspicuous on partly defoliated limbs. Since the branches where the nests are most numerous are similar in appearance to those resulting from saline effects this may be the initial factor, followed by the avian influence. If the birds prefer this type of nesting site their continuous fecal accumulations on the branches may further accentuate the effect. On the ground under the trees a rank odor prevails. Here the fecal whitened leaves of Asplenium, Nephrolepis and Guettarda are turning brown and dying. The high concentrations of fecal matter which accumulate in the soil may also have a detrimental effect upon the breadfruit.

Although the natives report that these birds have killed their trees in the past they were unable to indicate any trees recently killed in this manner. Today they constantly destroy the nests. Possibly this judicious care of their trees accounts for the lack of any recently killed.

On Tirakaume huge flocks of frigate birds roost in the coconut palms. From the fecal deposits there results an extremely unpleasant odor. At present no adverse effects are evident on the vegetation. However, the small size of the islet, the sparse flora and recent clearing make interpretation difficult.

The highly phosphatic soils in the interior of Pumatahati are of especial interest. This area was formerly covered with large Pisonia trees where large flocks of boobies and frigate birds nested. Around 1920 the Pisonia was cut and the area planted to coconut. Today, under the coconut, the soil is quite different from that on the other islets. An acidic dark brown humus layer pH 4.5 gives way to a brownish cemented layer containing 100% apatite. At 18 inches in depth this layer is less consolidated and crumbles easily. The formation of this distinctive soil type is presumably correlated with fecal deposits resulting from birds nesting in Pisonia trees (Fosberg 1954). The theory of origin of this soil profile is that the humus from Pisonia leaf litter is normally acid and the calcium phosphate deposited on this litter by the nesting or roosting birds is carried down into the humus by rain water. The calcium phosphate dissolves because of the acid reaction of the organic matter. When the solution reaches calcium carbonate beneath the humus, it becomes alkaline and phosphate precipitates out cementing the sands and gravel particles together into hardpan. With further bathing by this solution the calcium carbonate may become partially or wholly replaced by calcium phosphate.

With the exception of the lighter brown consolidated layer, the upper horizons are similar to those described by Fosberg (1954) as the Jemo soil series. Since the cementation and replacement processes probably ceased following the cutting of Pisonia, this lighter color is probably due to weathering. Although the cemented layer was not excavated to a sufficient depth to determine whether unconsolidated material was present, at 18" in depth pockets of very crumbly material were encountered. It would

appear that the process described was at least operative in part in the formation of this phosphatic complex. The coconut trees within this area exhibit extremely weird growth forms.

The presence of a larger bird population in the past has already been indicated in the case of Pumatahati islet. Prior to habitation birds were probably much more abundant. The presence of high concentrations of phosphorite in the interior of some islets and on the reef rock remnants is highly suggestive. Its presence in the reef rock suggests that these deposits probably occurred when these areas were vegetated. Since that time erosion has removed the vegetation and left only the projecting phosphatic remnants.

F. Mammals

The mammals represented include the Polynesian rat (*Rattus exulans*), cats and pigs. As reported by Miller (1953) rats are uncommon on the densely populated islets of Touhou and Werua where the cats are supposedly keeping them under control. In contrast, they are locally abundant in the living areas on some of the outlying islets. On Hare islet several were trapped during the day in a boat house. However, none was seen in the plantations and no damaged coconuts were observed. The pigs are small and inbred but are regarded as a luxury because coconut is their chief food. Since they are not permitted to roam in the plantations they are either tied to a tree or kept in pens made of coconut logs. Where they are tied in the plantations the area is completely uprooted and whenever they escape from captivity young breadfruit or other plantings may be destroyed.

VII Human influences

In interpreting the land ecology human influences are by far the most important. Man's influence is most evident in the origin of the present flora as well as in his manipulation and utilization of the vegetation (Table I).

Of the total flora over one-half of the species have been introduced by man. Several of the earlier introductions such as coconut, breadfruit, *Pandanus* and puraka now comprise the dominant vegetational aspect. Of lesser abundance, but more importance in numbers of species, are the more recent introductions. These consist primarily of ornamentals which are constantly being brought in from surrounding islands such as Ponape and Nukuoro. On Kapingamarangi, as well as other islands in the Pacific, man has played a very important role in the dispersion of plants as has been recently emphasized by Merrill (1954).

In contrast to the dominants, most of the species which comprise the understory are rarely propagated by man. Though unimportant in furnishing food, they provide a valuable source of wood for construction and other purposes. Therefore, throughout the plantations continuous clearing by cutting is quite selective; the larger better trees being spared. Another clearing technique involves burning the bases of large trees. Gnarled

Guettarda of little value are sometimes removed in this manner, as well as larger Premna, when competing with plantation species. In contrast, the dense herbaceous cover, primarily Wedelia and ferns, is entirely cleared by cutting or actual removal by pulling. However, roots and rhizomes, which again produce a lush growth, frequently remain. This general clearing of the undergrowth may be annual or more often, depending upon islet size and seasonal conditions. As previously mentioned, the sharp lines of demarcation which are evident throughout the understory are a result of differential clearing by the various land owners.

In addition to obtaining food and shelter from the land the natives also export some copra. This business reached its peak during the Japanese period when exports reached 300 tons per year. At that time Pandanus were frequently cut in order to allow more space for coconut. With American occupation exports have decreased considerably, now ranging from only three to thirty tons every two months. During July and August 1954 fifteen tons were exported. This decrease in copra production may be correlated with several factors. First, the population has been constantly increasing and second, there is an abundance of older less productive trees. In addition, the recent demand for their superb handicrafts now affords a new and equally good source of income. For example, the current demand for Pandanus mats has initiated extensive planting of Pandanus in lieu of coconut in certain instances. The most recent demand has been a contract for 100,000 square feet of mats. Therefore, the young Pandanus are being stripped of their leaves as rapidly as they mature. This emphasis on handicrafts is also reflected in the demand for Calophyllum whose wood is highly prized for coconut graters, some of which are sold. These trees are disappearing from the lagoon shore faster than they are being replaced. In general, however, the natives are extremely cognizant of their dependence upon their environment as is evidenced by the excellent care given their plantations. Further evidence is seen in their reluctance to sell a canoe, which means the loss of another large productive breadfruit, which must be used to build a new hull.

On an atoll comprising 0.42 square mile of land there is a very definite limit to the number of people such a microcosm can adequately support. Any crisis can precipitate a catastrophe. For example, the prolonged drought of 1916-18 brought death to ninety Kapingans. Of course, it was accentuated by the restriction placed upon the taking of coconuts and fish. Following this incident a Kapinga village was established on Ponape to relieve the situation. However, since 1920 the population of 300 on Kapingamarangi has been steadily increasing and reached a peak of 527 in 1947 at which time more people moved to Ponape. It is estimated that 450 is the limit which Kapingamarangi can support. With the present demands of the 426 natives now living on the atoll this figure approximates the limit: 0.64 acre per person.

VIII Climatic influences

Although numerous climatic factors modify the biota, several are of especial importance. Probably the most continuously operative is that of prevailing winds laden with salt spray. Throughout the summer when the

Species	Wood	Leaves	Fruit	Root	Flowers
**Cocos nucifera	*construction	mats, baskets *roofing, brooms, food wrapping, torches, "fishing rope"	1.green:*water, baby food 2.mature:*food, copra, oil 3,sprouted:food, husk: *rope, fuel, "toilet tissue"		sweet drink
**Artocarpus altilis	*canoe construction, canoe bailer, Kamit boxes, crafts: model canoes, bowls	food wrapping, ground oven	*food		
**Pandanus tectorius		*mats, baskets, *roofing	*food	string from prop roots	
**Cyrtosperma chamissonis				*food	
Guettarda speciosa	*construction, implements			shark hook	lei
Morinda citrifolia	*construction				
Premna obtusifolia	*construction, *canoe paddle				
**Calophyllum inophyllum	construction, implements, *crafts				lei
Messerschmidia argentea	implements, crafts				
Cordia subcordata	construction, implements				
**Hibiscus tiliaceus	implements, *canoe pole, bark: lava-lava				
Clerodendrum inerme	fish trap				
Tacca leontopetaloides				food-source of starch	
**Musa spp.		ground oven	food		

TABLE I - Utilization of species.

* major uses.
** species present primarily as a result of planting.

rainfall is frequently at a minimum this salt spray, combined with the drying effect of the wind, has pronounced effects upon the vegetation. Although the atoll is outside the typhoon belt, another but more erratic influence is that of the severe storms which can modify the vegetational pattern for many years thereafter.

While the dominant vegetation is tolerant of saline influences, its degree of tolerance varies. For example, among the marginal species the foliage of Guettarda is more easily damaged than that of Scaevola. Oceanward the leaves of the former show a general browning of the margins while lagoonward this is not at all evident. In contrast, Scaevola is unaffected except for occasional shrubs with dwarfed rosettes of leaves. Along the marginal areas as well as in the interior of some of the smaller islets the lower coconut fronds are often brownish and dying. However, the success of these three species along the marginal areas would suggest that these effects are relatively superficial. In contrast, other marginal species of lesser importance such as Cordia and Terminalia samoensis are more adversely affected, which may account for their minor role. All Terminalia observed were extremely depauperate with only a few leaves at the ends of the branches which exhibited very slow growth. Another species, Cordia, shows considerable wind sheared, or as is probably more correct, spray sheared effects (Fosberg 1953). Here many of the stems were killed back 6-12 inches or more by the end of the survey. This condition may be the result of a combination of salt spray and drought since the rainfall during the survey was extremely low.

Whenever typical interior species such as Premna and Morinda occur in the marginal zone, probably as a result of erosion inland, dead or dying branches are evident and leaves show marked salt spray damage. A similar condition is present where the marginal vegetation is absent and the full force of the salt laden winds directly strikes the unprotected undergrowth in the interior. Where the breadfruit canopy projects above the surrounding coconut, dead or defoliated branches are evident. According to the natives the upper branches frequently lose their leaves following a severe storm. However, new ones usually appear later. Ground water salinity (see section on Ground Water Influences) is apparently another interacting factor which is fundamental in delimiting the breadfruit distribution (Fosberg 1949). Another species very sensitive to salt spray is Calophyllum which is planted exclusively along the lagoon shore. The lone specimen observed oceanward showed both salt spray damage and serious insect infestation.

In order to give some idea of the relative tolerance of the more common species a list follows beginning with the most salt tolerant group.

Cocos nucifera
Pandanus tectorius
Messerschmidia argentea
Saaevola sericea
Guettarda speciosa
    Cordia subcordata
    Clerodendrum inerme
        Terminalia samoensis
            Premna obtusifolia
            Morinda citrifolia
                Calophyllum inophyllum
                    Artocarpus altilis

As previously mentioned, periodic droughts occur. Although the effects of the 1916-18 drought are not completely known, at least coconut and breadfruit production was greatly reduced at that time. Shorter periods, such as a summer of low precipitation, can also result in decreased production. Even in the puraka pits where the ground water lens is usually at the surface the replacement of taro by puraka is attributed to the greater drought resistance of the latter. These dynamics may also be operative in other areas.

Although the lack of typhoons lends a remarkable stability and uniformity to the plantations compared to that of other atolls, periodic storms or tidal waves result in sporadic damage as revealed by the data available back to 1858. These earlier storms (1858, 1886, 1896) all resulted in numerous windthrows and damaged or dead trees. Around 1920 a thunderstorm resulted in the loss of considerable coconut. A 1937 storm was followed by one in 1947 which was probably the most severe during this generation. At that time salt water inundated the interior on the lagoon sides of Touhou, Werua, Ringutoru and possibly others. On Ringutoru six puraka pits were destroyed by the salt water. An estimated sixty-seven breadfruit and ten coconut were killed or windthrown and many others suffered damage but remained alive. Today some of these large breadfruit, probably killed or weakened by this storm, still stand within the breadfruit-coconut zone. Many of the breadfruit killed were removed and utilized for canoes or general construction following the storm.

IX Physiographic influences

Erosion and deposition are constantly modifying the islets and subsequently the vegetation. Erosion on the oceanside is undermining and removing marginal species such as coconut, Guettarda, and Scaevola. During bad storms the smaller islets are severely eroded. For example, during the storm of 1858 Matukerekere, then about 0.7 acre in size, was completely destroyed. However, rebuilding occurred until by 1947 it supported ten coconut, when another storm destroyed nine of them as well as most of the islet. Immediately upon our arrival the meager vegetation of this 25 by 100 foot islet, comprising one mature coconut and five immature chlorotic palms and numerous drift seedlings, was accurately mapped. A remapping after seven weeks indicated that 25% of the land surface had been washed away including one of the smaller coconuts and numerous drift seedlings. No storms of any consequence occurred during this period indicating the ease with which these smaller islets undergo retrogression. On the sand bars continuously forming lagoonward, new areas are constantly being exposed for the invasion of pioneers such as Scaevola and associated species (see section Marginal Vegetation). Recently this process has been accelerated on some islets by the construction of coral boulder causeways across the channels.

Although no one species appears to be restricted to a particular site, certain species are more abundant and characteristically found in certain areas. For example, on the boulder beach ridge Guettarda is most typical. Since seedlings frequently occur its success here is apparently correlated with its ability to get established in this boulder complex. Although

herbaceous cover is usually sparse or absent, *Asplenium* readily becomes established wherever coconut husks occur on the large boulders. In the interior its restricted occurrence on old coconut stumps, bases of trees and other organic matter would indicate the importance of an organic substrate for its establishment. On the unaltered sandy soils, such as the recently formed sand bars, *Scaevola* and *Messerschmidia* are typical pioneers. Herbaceous species commonly found in sandy areas include *Lepturus repens*, *Fimbristylis spathacea*, *Ipomoea pes caprae* and *Triumfetta procumbens*.

Although mineral analyses of the soils are not yet available, no striking deficiencies were evident such as those reported from Arno Atoll in the Marshall Islands (Hatheway 1953). However, on the recently deposited sands, with little or no organic matter, the smaller coconut are very chlorotic. Along the marginal areas *Scaevola* leaves are often yellowish-green or covered with yellow spots. In the living areas the leaves of banana are also chlorotic. In these instances the casual factor is probably a nitrogen deficiency. The lack of organic matter also retards the growth of coconut. This is especially evident on the recently filled Herengaua causeway on Hare islet. Here coconut planted circa 1943, prior to the ones in the adjacent bombed areas, are smaller and merely attaining the productive stage. In contrast, those planted since the war on Hare, circa 1946, are taller and producing fruit. A similar situation is evident on the recently deposited sands forming Pepeio.

Mature chlorotic coconut trees of low productivity are rare. On Torongahai these occur on a narrow elevated bank dividing two puraka pits. Here restriction of root development, rather than a mineral deficiency, may be the causal factor.

X Ground water influences

The role of ground water salinity in the restriction of breadfruit to the interior regions has been suggested by several investigators (Fosberg 1949; Cox 1951). From present studies it is apparently controlled by a complex of factors; namely, previously mentioned storms, salt spray, ground water salinity as related to soil permeability, and minor topographic differences in elevation.

During storms, salt water frequently inundates the islets resulting in breadfruit damage. Many trees which were killed as a result of the 1947 storm are still standing.

As previously mentioned, the upper exposed branches of many trees are killed back or defoliated by salt spray. However, the effects of ground water salinity appear quite similar. An incident which occurred during the summer is indicative of this. During a high tide accompanied by strong winds and accentuated by a causeway obstructing the natural flow of water between islets, salt water rose to within 50 feet of a small breadfruit 5 inches in diameter. The leaves turned brown and a month later four branches were dead and some brown leaves still persisted.

Ground water samples were analyzed from dug wells and puraka pits where breadfruit occurred in order to determine, if possible, its distributional pattern in relation to salinity (Table II). Within the breadfruit-coconut plantations, the extremes ranged from 18 ppm. on the lagoonward side of Torongahai to 3,840 ppm. near the ocean on Nunakita. Although the trees are in good condition on both islets, their relative size and abundance differ considerably. On Torongahai they are larger, 3-4 feet in diameter, and more continuous in contrast to Nunakita where they are only 1-1½ feet in diameter and very localized. The latter, near a bomb crater, are apparently post-war plantings. In the pure breadfruit grove on Werua, where some of the largest trees occur, the salinity ranged from 28-46 ppm. In general, the larger and more productive trees are found from the center of larger islets lagoonward where the salinity is less than 350 ppm. This compares favorably with the 300-400 ppm. mentioned by Cox (1951).

The interrelationship of the soils, bedrock, and salinity, as affecting breadfruit distribution, is also of interest. Oceanward, the bedrock and coarse overlying materials more readily permit the movement of salt water in contrast to the fine sandy sediments lagoonward. Therefore, the breadfruit extend closer to the lagoon shore where the water is less saline than oceanward where salinities rise rapidly as one approaches the beach ridge. On Torongahai, where the lowest salinity was recorded, the parent material is dominantly sand and scattered rubble, and bedrock outcrops are absent compared to the other larger islets. The influence of this sandy substrate is also evident on one of the smaller islets, Parakahi (3 acres) where, although no breadfruit are found, the salinity is lower compared to other larger islets with breadfruit which are covered by rubble and underlain in part by bedrock.

On several islets marked fluctuations in the salinity occurred between the two sampling periods. The salinity increased in all six wells on Taringa and Werua as well as the community well on Touhou (Table II). These increases might well be correlated with the low precipitation (4 inches) during seven weeks of the survey. Although breadfruit is not usually considered a phreatophyte (a plant which utilizes water from below the water table) during such dry periods the vadose water (that water held in the soil above the water table) may be inadequate and through capillary rise the underlying salt water may exercise adverse effects (Cox 1951). If this was the case, it was not yet evident at the end of the survey. However, some wilting of the other vegetation occurred, especially in the exposed sites.

On one of the smaller islets, Hukuhenua, 5 acres in size, the salinity fluctuation was very erratic. Here, in contrast to the increases previously recorded, a marked decrease occurred between the sampling periods. The first sample was quite salty (1,740 ppm.) while the second was relatively fresh (480 ppm.). The few breadfruit were in poor condition and one dead tree was evident. In this case the small size of the islet, the erratic salinity fluctuation, and the condition of the breadfruit suggest a relatively shallow fresh water lens. Therefore, changes in the salinity would be easily affected. For example, light rains, or even very high tides could cause considerable fluctuations and storms would result in even greater changes.

ISLET	OCEANWARD high (tide)	OCEANWARD low	MIDDLE OF ISLET high (tide)	MIDDLE OF ISLET low	LAGOONWARD high (tide)	LAGOONWARD low	REMARKS
Taringa							
7/30	2600	2600	776	900	100	106	Dug wells; breadfruit-coconut type occurs from middle of islet lagoonward; breadfruit large and productive.
8/20		3800		1100		340	
Werua							
7/30	2200	1000	28	28	30	28	Dug wells; one of the largest islets; breadfruit-coconut and pure breadfruit types dominate areas sampled; very productive.
8/20		2860		46		54	
Parakahi							
7/30					380	380	Dug wells; small lagoonward islet; parent material dominantly sand; coconut plantation excellent; no breadfruit.
8/20						380	
Hukuniu							
7/30	16,800	17,480					Dug well; oceanward islet; dominantly bedrock; sample taken lagoonward; no noticeable adverse effects on coconut, although extremely xeric and lacking in herbaceous cover; no breadfruit.
8/20	16,840	16,440					
Hare							
8/6			(56)				Puraka pit; breadfruit productive.
8/19			(310)				
Touhou							
6/26			(202)				Community well; upon arrival. Breadfruit very productive.
7/31			(214)				Following rain.
8/8			(284)				----------
8/27			(286)				Upon departure.
Matiro							
8/18			(50)				Puraka pit; breadfruit good condition.
Torongahai							
8/14			18				Puraki pit; breadfruit large, very productive.
Nunakita							
8/25	3,480						Bomb crater; breadfruit 10-12 in. d.b.h.; good condition; no fruit evident.
Takairongo							
8/16				140			Puraka pit; breadfruit vigorous.
Hukuhenua							
8/17				·1,740			Puraka pit; breadfruit very poor condition; many dead or defoliated branches; one dead tree.
8/27			(480)				

TABLE II - Salinities (ppm.) of Ground Water Samples. Data ascertained by silver nitrate titration technique. On the wider islets oceanward samples were taken approximately 100 ft. from high tide mark; lagoonward samples 50-100 ft. Tide level data not available for those salinities in parentheses. For comparison, salinity of ocean water 17,760 ppm. near breakers; lagoon water 19,600 ppm.

Since only scattered trees are present on islets less than five acres, this apparently approaches the minimum size where breadfruit culture is feasible on this atoll. Of course, some variability occurs depending upon geological structure. On Hukuhenua the underlying materials are primarily loose rubble and boulders with slight cementation at 3-4 feet in depth. In contrast, on the even smaller sandy islet of Parakahi, less saline conditions were encountered. Therefore, breadfruit would probably grow more successfully on Parakahi than on Hukuhenua even though the islet is smaller. This emphasizes the importance of the substrate as well as islet size in regard to breadfruit distribution.

Another possible factor involved in breadfruit distribution is the minor differences in topography. The slightly higher elevations oceanward where the water table is 5-5½ feet below the surface, may account for the younger breadfruit extending as far oceanward as they do. In these areas, even during dry periods, it is doubtful whether capillary action would occur through the coarse materials to the point of reaching the roots of these smaller trees. Other elevated areas include the puraka banks. An observation made on Hare concerning the role of these banks is pertinent. Here two trees of equal size which occurred practically at equal distance from the lagoon, one on the bank and the other several feet below, were very differently affected by the 1947 storm. The tree on the bank several feet above the average level of the islet shows no adverse effects. In contrast, the adjacent tree, located off the bank at a lower level, was killed. On the somewhat raised islet of Touhou this may account for the presence of large productive breadfruit trees which extend closer to the beach there than on any of the other islets. The presence of these trees on the banks throughout the entire atoll may in part account for their survival during severe storms and other critical periods. Observations over a longer period are needed before definite conclusions can be drawn on the interaction of these various influences as related to breadfruit distribution.

In contrast to breadfruit the distribution of coconut is not noticeably influenced by salinity. Although the trees are largest and most productive on the larger islets where the salinity is low, vigorous and productive trees completely cover the smaller islets, such as Hukuniu, where the ground water salinity is comparable to that of the ocean.

XI Biotic influences

Since the faunistic aspects have been discussed under Associated Fauna this section will consider the floristic and vegetational aspects.

Only one species, the parasite Cassytha filiformis, has any direct adverse effects upon its associates. It is most commonly found on Scaevola and Guettarda. Here it forms such dense tangles around the stems and leaves that portions of the former are frequently killed.

The influence of the marginal vegetation as an interceptor of salt spray, and therefore a protector of the interior areas, has been mentioned. The more mesophytic character of the vegetation on Ringutoru and Torongahai

may be correlated with the dense continuous band surrounding these islets in contrast to the other larger ones lacking a comparable border. In addition, this may have also been accentuated by less clearing of the understory which, over a long period, would add to the mesic condition. At least today the understory is extremely dense compared to that on the other islets. However, an equally important factor is their more oval shape, along with their considerable width.

Another protective aspect of the vegetation is evident in a technique occasionally employed by the natives to protect their young breadfruit. This involves leaving a small circular stand of vegetation such as Morinda around smaller trees in order to reduce the direct effects of salt spray.

In a region of extremely immature soils, possibly the most important influence of the vegetation is in soil formation as a result of organic accumulation. Although the depth of organic development averages 6-8 inches in the rubble areas, it is usually much less in the sandy soils which are of more recent origin. However, on two islets extreme organic accumulations were encountered: Tokongo, 18 inches and Rikumanu, 30 inches. If it can be assumed that the degree of accumulation is proportional to the length of time the area has been vegetated without disturbance, it would appear that these two islets have had the least disturbance in the past. When the topographic features are examined this seems likely, especially for Rikumanu. Here the islet is elevated on a bedrock pedestal several feet higher above sea level than any of the others. Therefore, it may not have been subjected to the constant erosional and depositional action operative on the other islets in the past. Although no noticeable topographic difference was evident, on Tokongo the slightly greater accumulation of organic material may merely indicate the chance of somewhat less disturbance than occurred on the surrounding islets. It is interesting to note that this islet has the largest number of species for its size and is dominated by a Premna-Morinda understory similar to that found on the larger more mesic islets. This may also reflect its longer existence.

The rate of organic accumulation was also investigated by studying the depth of the organic layer on the two Hare islet causeways. The older Rawa-Hare causeway, which filled in about 100 years ago is of especial interest. In several samples the maximum accumulation of organic material was approximately 1 inch since about 1865. This would indicate that in sandy soil under a coconut type vegetation the rate of organic accumulation is about 1 inch per century. If this figure is now applied to Rikumanu islet where 30 inches was detected the length of time involved would be about 3,000 years. This dates back to the end of the xerothermic period which occurred from 3,000-6,000 years ago (Flint & Deevey 1951). During the peak of the xerothermic it is presumed that the ocean level was several feet higher than at present. Therefore, the islets may not have been formed until the end of the xerothermic or approximately 3,000 years ago, which correlates with the organic accumulation evidence here presented. Further research is necessary before definite conclusions can be formulated since this represents one isolated example.

PAST VEGETATION AND PRESENT TRENDS

Since the entire land area is now under extensive management a reconstruction of the past vegetation, prior to the arrival of man, is extremely hypothetical. There is little evidence of a continuous aspect comparable to the present coconut and breadfruit except on Pumatahati. Here, as formerly mentioned, a large Pisonia forest dominated until around 1920 when it was cut in order to expand the coconut plantations. Today all that remains is the base of one of these large trees and the understory is dominated by their stump sprouts. The presence of a similar understory occurring locally on other islets would suggest the former importance of Pisonia. From their present role Guettarda and Premna probably comprised the dominant aspect. Even in the recent past these species were more important and occurred as larger trees. Other species such as Hernandia sonora, Ochrosia oppositifolia, Cerbera manghas, Thespesia populnea, and Soulamea amara possibly occurred either as scattered trees or locally as pure stands. The herbaceous flora was very limited. Those represented, such as ferns and grasses, formed a dense ground cover. The marginal vegetation was probably similar to that found today except for its greater density. Along the beaches a few pioneers may have been present. However, the restricted distribution of these species today suggests that they are relatively recent to Kapingamarangi.

Within the last century several changes have occurred. From the natives it was learned that breadfruit and Pandanus were more abundant in the past. Although little evidence was found for the former, the decrease in Pandanus probably resulted from cutting during the Japanese regime in order to make room for more coconut. However, with American occupation Pandanus is again on the increase because of the current demand for mats and other handicrafts. Although man plays the dominant role in regulating the abundance of coconut, breadfruit, and puraka, Pandanus reproduction in the plantations is of considerable importance. The natives claim that such trees produce only useful leaves and that the fruit is of inferior quality. With man's continual clearing there is little indication of successional change in the understory. Only on sandy lobes of the larger islets is a successional trend evident from the early pioneers - Scaevola, Messerschmidia and Guettarda - to a Premna-Morinda type. On the recently formed sand bars, Scaevola and Messerschmidia are the typical pioneers. Even in this early stage, coconut are planted and as the plantations develop Guettarda also becomes a part of the understory. However, eventually a succession similar to that described above occurs. In the over-all plantation complex, areas of breadfruit-coconut type are expanding into the pure coconut plantations while the latter is expanding onto the continuously forming sand bars. A slight increase in puraka areas is evident within the breadfruit-coconut plantations. Although introduced species are now very abundant, especially in the living areas, their role may be of even greater importance as native travel is facilitated.

SUMMARY

1. Kapingamarangi Atoll comprises thirty-three islets representing 0.42 square mile. Due to man's influence, the entire area is dominated by coconut, breadfruit, Pandanus, and puraka (Cyrtosperma chamissonis). Although coconut plantations dominate the smaller islets, on the larger ones a typical zonation is evident. Here coconut plantations form an outer band and give way in the interior to an admixture of breadfruit and coconut, or pure breadfruit, interspersed with puraka pits.

2. The strand vegetation, of dominantly indigenous species, is restricted primarily to the undergrowth and marginal areas. On the smaller islets the understory is predominantly Guettarda speciosa, while on the larger ones Morinda citrifolia and Premna obtusifolia are most conspicuous in the plantations. On all islets Pandanus is relatively common as scattered trees or as extensive plantings on the puraka banks. Herbaceous cover increases on the larger islets. Here Asplenium nidus, Nephrolepis hirsutula, and two grasses, Stenotaphrum micranthum and Thuarea involuta are most typical. This entire pattern is continuously being modified by man's clearing operations.

3. The marginal vegetation comprises a conspicuous border of Guettarda and Scaevola. Although the former is common throughout, Scaevola is most important in the less severely eroded sectors. On the recently formed sand bars, Scaevola is the characteristic pioneer.

4. The inhabited areas are also dominated by breadfruit and coconut. However, the undergrowth is predominantly Pandanus with an abundance of recent introductions.

5. Of the vascular flora, comprising ninety-eight species, thirty-eight are estimated as indigenous, fifty-eight introduced, and four as drift seedlings not yet established as mature specimens.* On the nineteen islets 3.5 acres or less in size, the number of species found is relatively uniform in contrast to the larger ones where a general increase in number of species occurs with islet size.

6. Man's influence is most evident in the origin of the present flora as well as in his manipulation and utilization of the vegetation. Some copra is exported. In addition, the native handicrafts, among the finest in the Pacific, are increasing in importance.

7. Of the associated fauna, insects, land and hermit crabs, skinks, geckos, and birds are most common. Land crabs play a vital role in the incorporation of organic matter into the soil. The more important land nesting birds include starlings, noddy and white-capped terns. Due to their gregarious nesting habit, the latter are reported to have killed breadfruit in the past. Although no such killed trees are evident today, the natives' judicious removal of the nests may account for the lack of them.

*Since two species are considered to have more than one means of entry, the various categories, when totaled, slightly exceed the actual flora.

8. Among the climatic influences, the salt laden winds, accentuated by extremely dry periods, modify the vegetation considerably. Those species most tolerant of salt spray include coconut, Scaevola, Messerschmidia, Pandanus, and Guettarda. In contrast, those most sensitive are breadfruit and Calophyllum. Although severe storms occur the lack of typhoons lends remarkable stability and uniformity to the plantations.

9. No restriction of species to a particular soil type was evident. However, Guettarda is most abundant in the bouldery areas while Scaevola, Lepturus repens, Ipomoea pes caprae, and Triumfetta procumbens are typical on the sandy soils. Although no striking mineral deficiencies are evident, chlorotic coconut and banana occur wherever the soils are lacking in organic development. Evidence of the Jemo soil series, presumably correlated with birds nesting in Pisonia trees, is found on Pumatahati.

10. The complex of factors apparently operative in breadfruit distribution includes salt spray, ground water salinity, and minor differences in topography. Breadfruit attains its maximum development lagoonward on the larger islets where the salinity is usually less than 350 ppm. Oceanward the salinity is higher in the bedrock areas overlain with coarse rubble and boulders. In contrast, it is lowest in the sandy-rubble soils lagoonward. This accounts in part for the present distributional pattern. Although variation occurs, depending upon the substrate, the minimum size islet where breadfruit culture is apparently feasible is about 5 acres.

11. Although the marginal vegetation is of considerable importance in the interception of salt spray, a more important influence of the vegetation is in soil formation. Extreme organic accumulations on several islets may indicate less disturbance in the past. When the rate of accumulation, approximately 1 inch per century, is applied to these areas the time involved would be 3,000 years. The presumed origin of the islets at this time correlates with the organic accumulation.

12. The past vegetational pattern is extremely hypothetical. Although there is little evidence of an aspect comparable to the coconut and breadfruit plantations, Guettarda, Premna and other larger indigenous trees, such as Pisonia, probably comprised the dominant vegetation. Although there were fewer herbaceous species those present possibly formed a more continuous cover. Marginal areas were probably similar except for an increase in density.

13. Today in the over-all plantation complex, areas of the breadfruit-coconut type are expanding into the pure coconut plantations while the latter is expanding onto the continuously forming sand bars. A slight increase in puraka is evident within the breadfruit-coconut type. Although recent introductions are especially common in the living areas, they will probably continue to increase as native travel is further facilitated.

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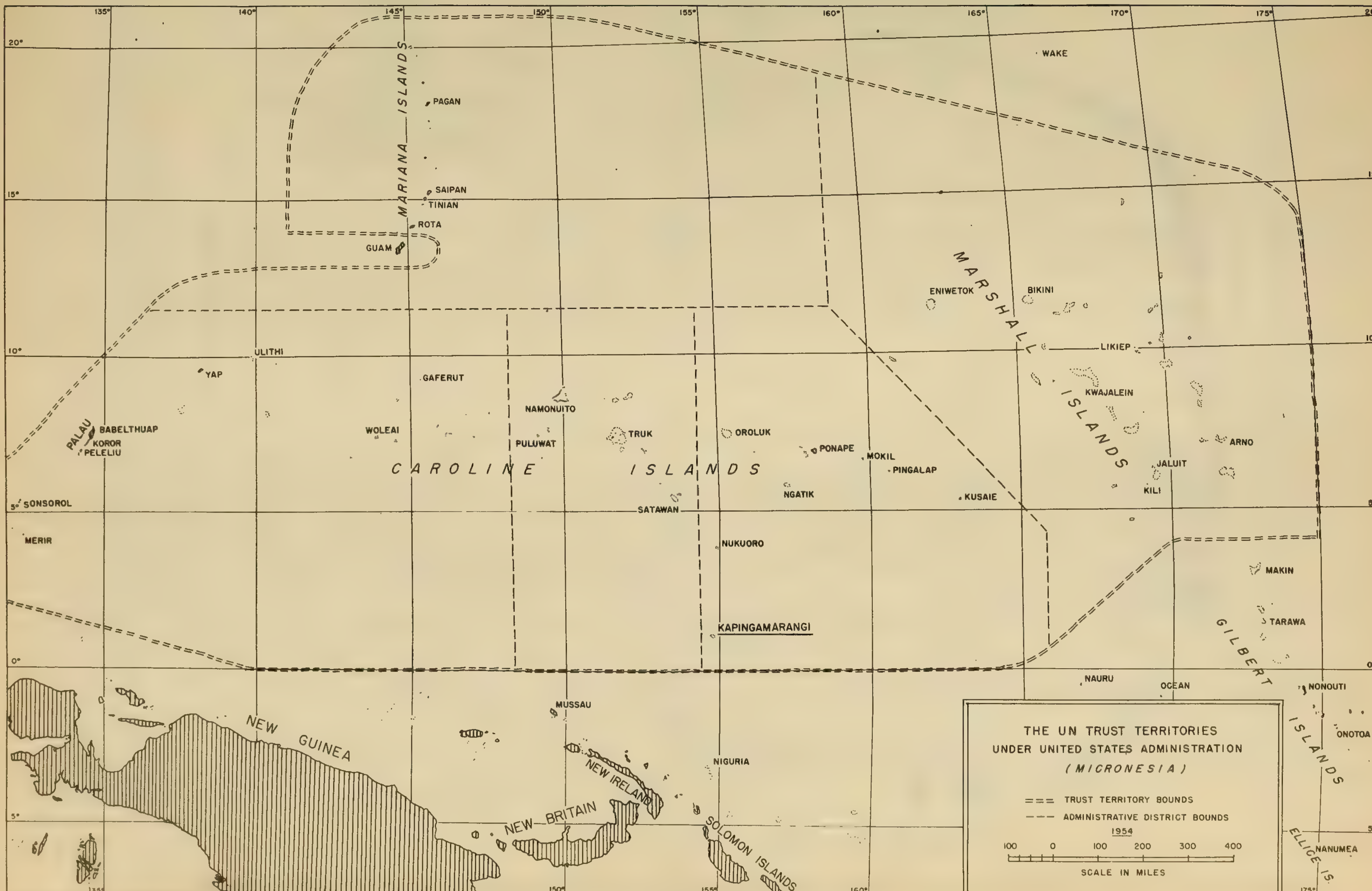

THE UN TRUST TERRITORIES
UNDER UNITED STATES ADMINISTRATION
(MICRONESIA)
TRUST TERRITORY BOUNDS
ADMINISTRATIVE DISTRICT BOUNDS
1954
100 0 100 200 300 400
SCALE IN MILES
MARIANA ISLANDS
PAGAN
SAIPAN
TINIAN
ROTA
GUAM
WAKE
MARSHALL ISLANDS
ENIWETOK
BIKINI
LIKIEP
KWAJALEIN
ARNO
JALUIT
KILI
CAROLINE ISLANDS
ULITHI
YAP
GAFERUT
NAMONUITO
WOLEAI
PULUWAT
TRUK
OROLUK
PONAPE
MOKIL
PINGALAP
NGATIK
KUSAIE
SATAWAN
NUKUORO
KAPINGAMARANGI
PALAU
BABELTHUAP
KOROR
PELELIU
SONSOROL
MERIR
NAURU
OCEAN
MAKIN
TARAWA
GILBERT ISLANDS
NONOUTI
ONOTOA
ELLICE IS.
NANUMEA
NEW GUINEA
MUSSAU
NEW IRELAND
NEW BRITAIN
NIGURIA
SOLOMON ISLANDS

FIGURE I

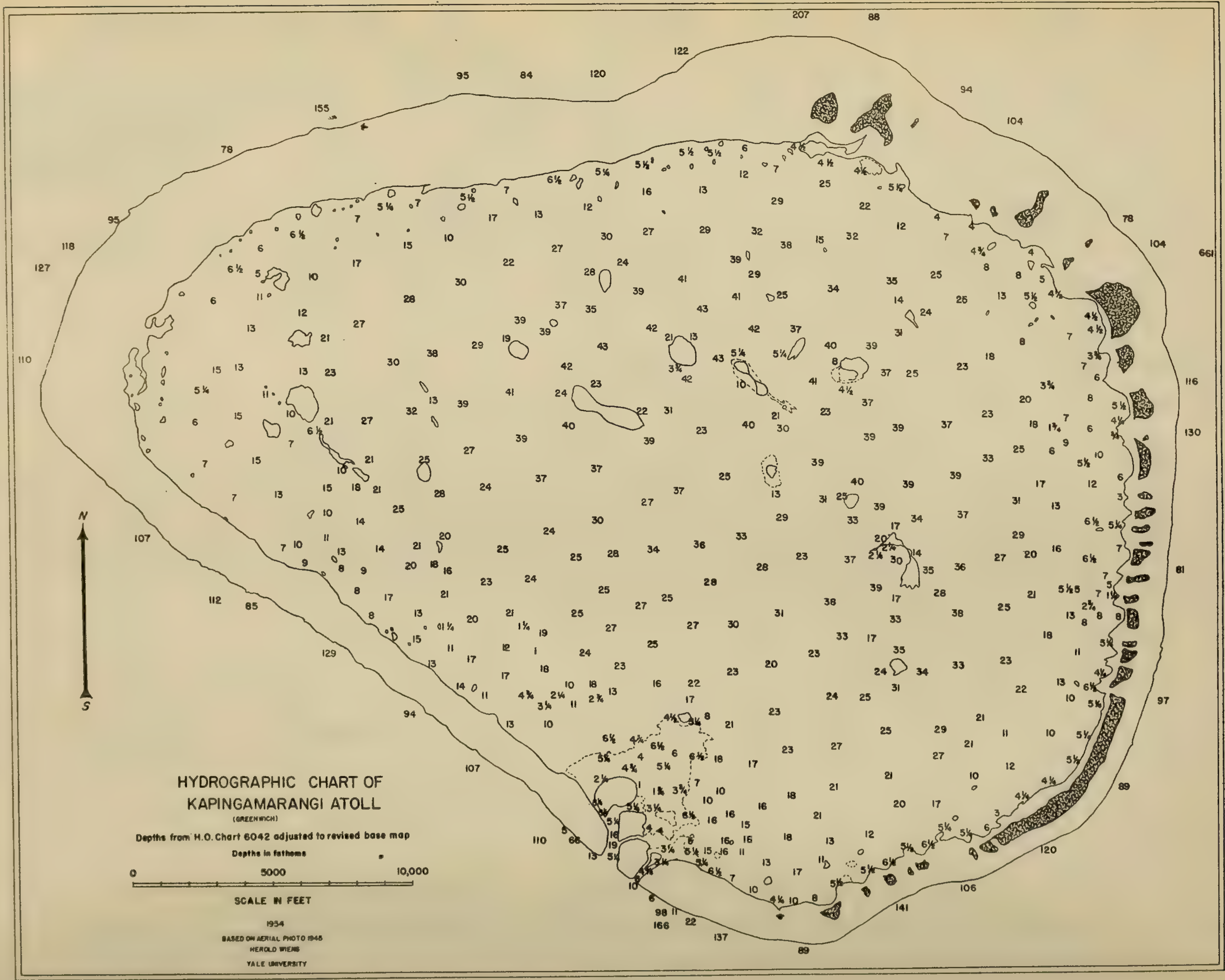

HYDROGRAPHIC CHART OF
KAPINGAMARANGI ATOLL
(GREENWICH)
Depths from H.O. Chart 6042 adjusted to revised base map
Depths in fathoms
0
5000
10,000
SCALE IN FEET
1954
BASED ON AERIAL PHOTO 1948
HEROLD WIENS
YALE UNIVERSITY
N
S

FIGURE 2

TORONGAHAI
RINGUTORU
RIKUMANU
TURUAIMU
PEPEIO
NUNAKITA
HUKUNIU
PARAKAHI
WERUA
TOUHOU
TARINGA
PUNGUPUNGU
MATIRO
MATUKETUKE
RAMOTU
SAKENGE
MATAWHEI
HUKUHENUA
HEPEPA
TIPAE
TETAU
NIKUHATU
TAKAIRONGO
TANGAWAKA
HARE
HEREKORO
TIRAKAU
TIAHU
TARIHA
TOKONGO
TIRAKAUME
PUMATAHATI
MATUKEREKERE
GREENWICH PASSAGE
N
S
KAPINGAMARANGI
0
5000
10,000
SCALE IN FEET
1954
BASED ON AERIAL PHOTO 1945
HEROLD WIENS
YALE UNIVERSITY

FIGURE 3

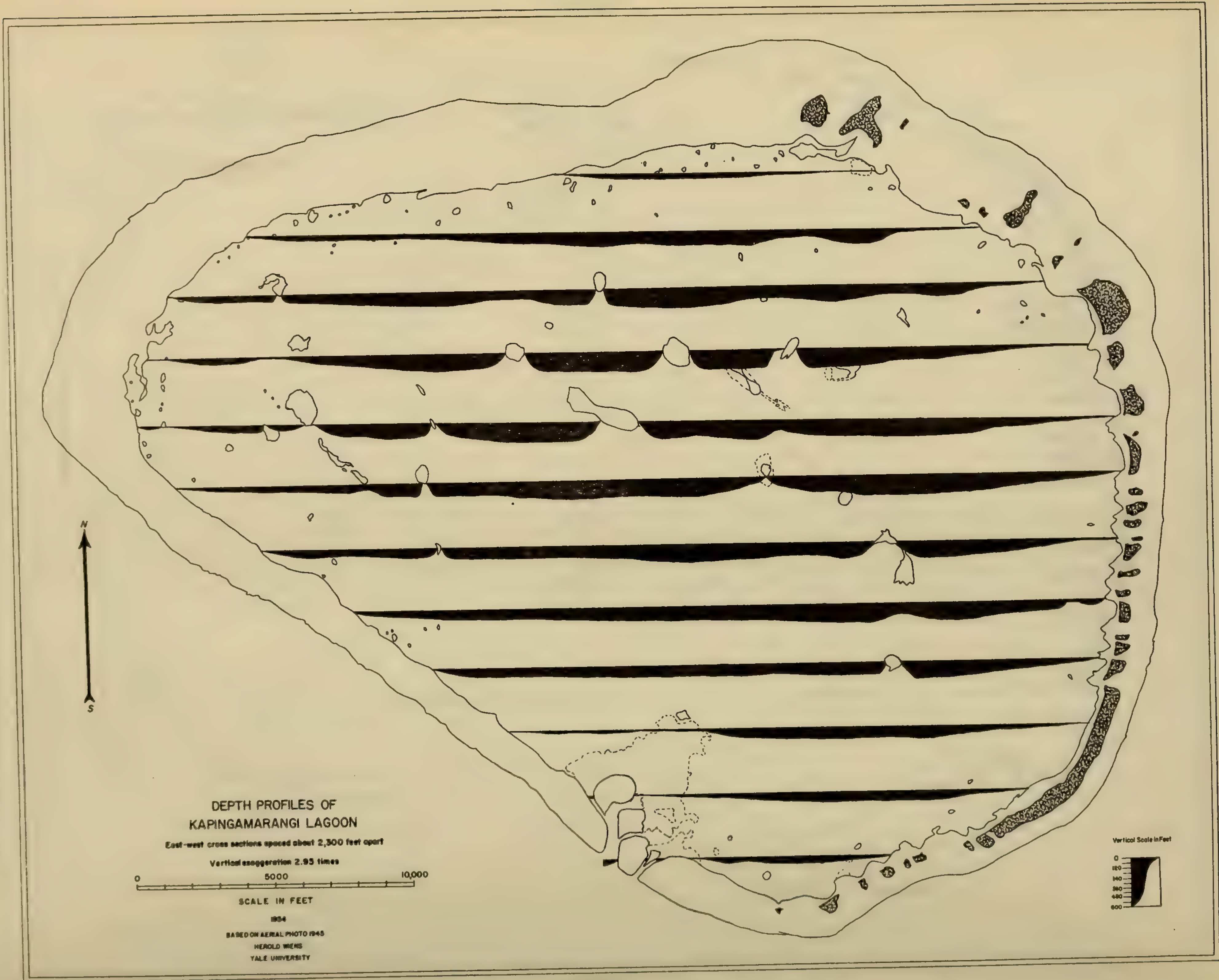

DEPTH PROFILES OF
KAPINGAMARANGI LAGOON
East-west cross sections spaced about 2,300 feet apart
Vertical exaggeration 2.93 times
0
5000
10,000
SCALE IN FEET
1954
BASED ON AERIAL PHOTO 1945
HEROLD WIENS
YALE UNIVERSITY
N
S
Vertical Scale in Feet
0
120
240
360
480
600

FIGURE 4

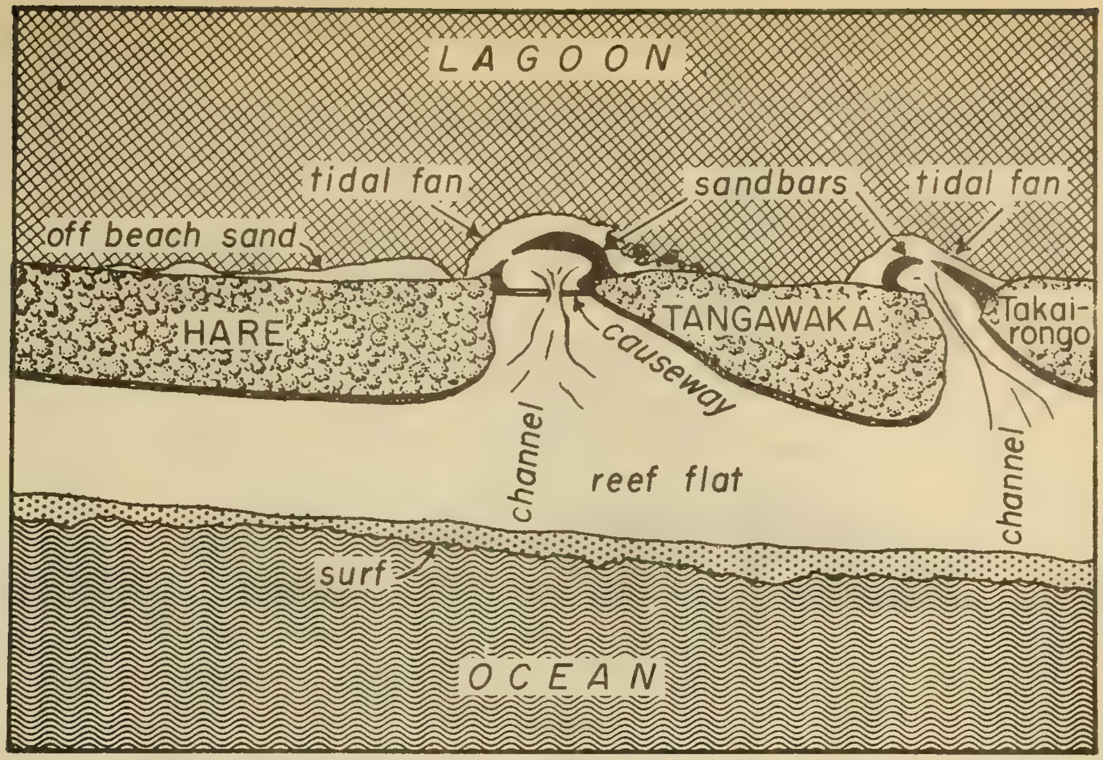


Figure 5

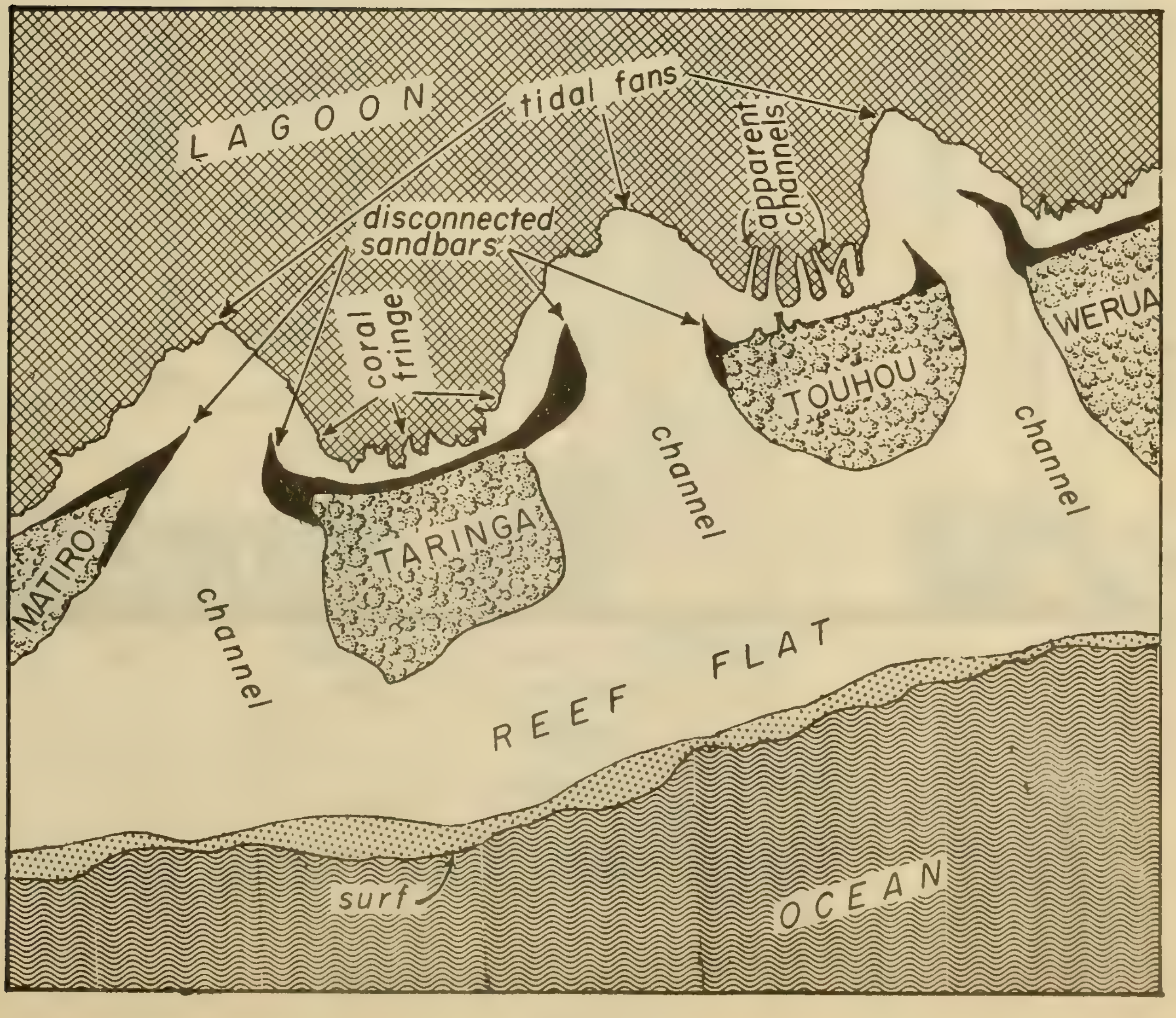
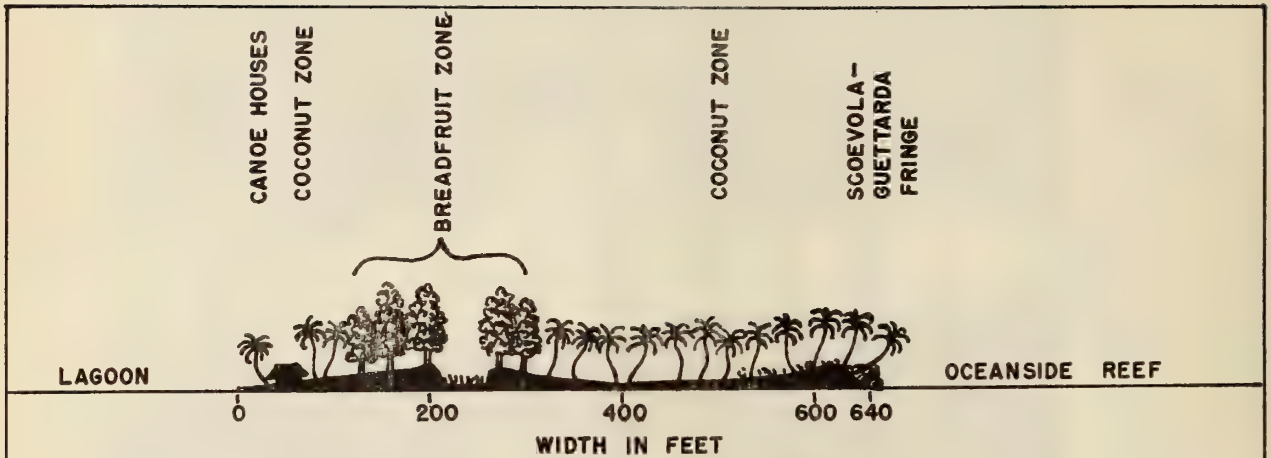
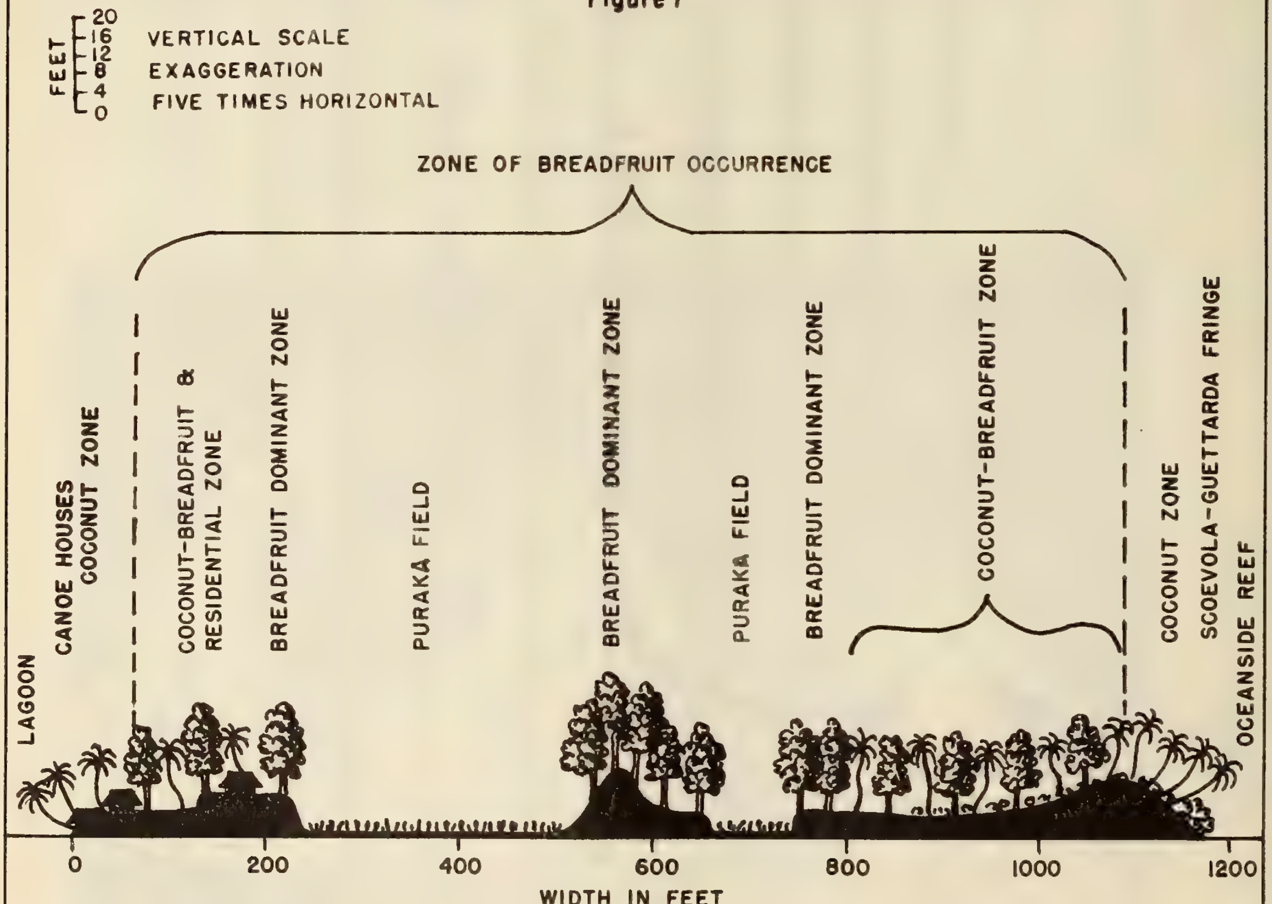


Figure 6



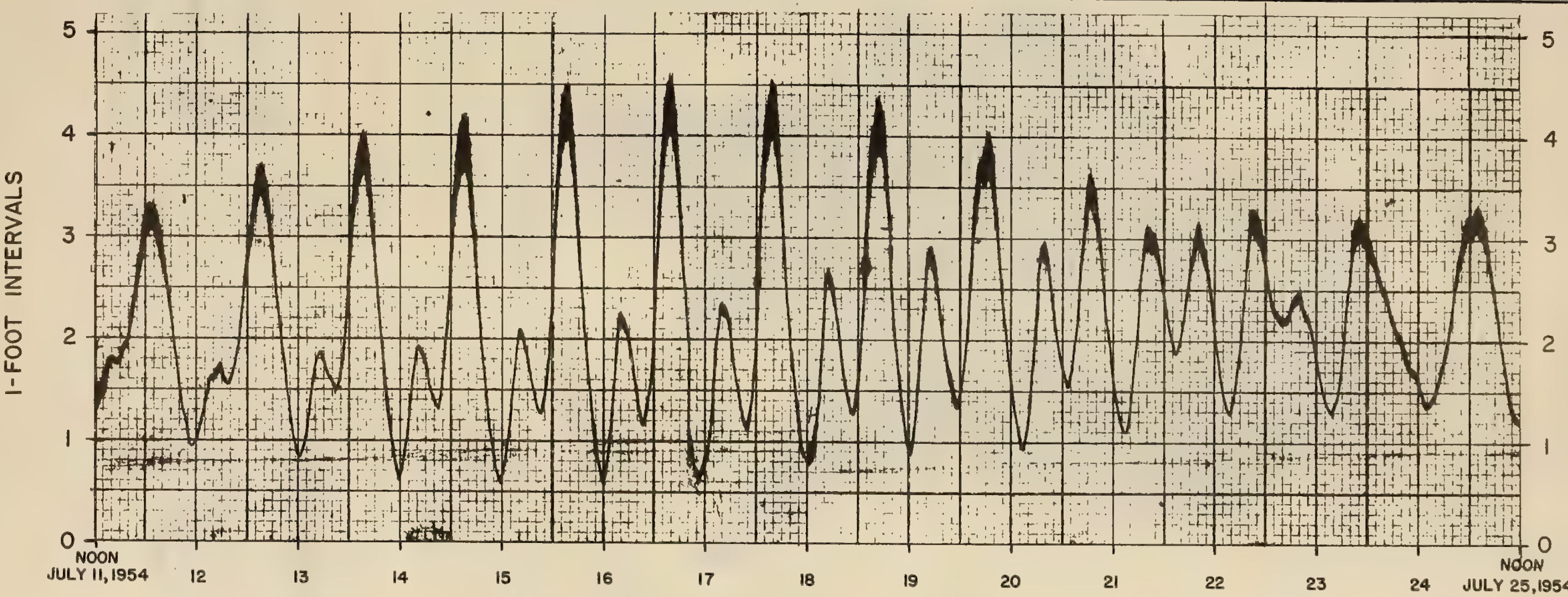
TARINGA

Figure 7



WERUA

Figure 8



Tidal fluctuations at the lagoon dock at Touhou Islet,
Kapingamarangi
Noon July 11 to Noon July 25, 1954

FIGURE 9

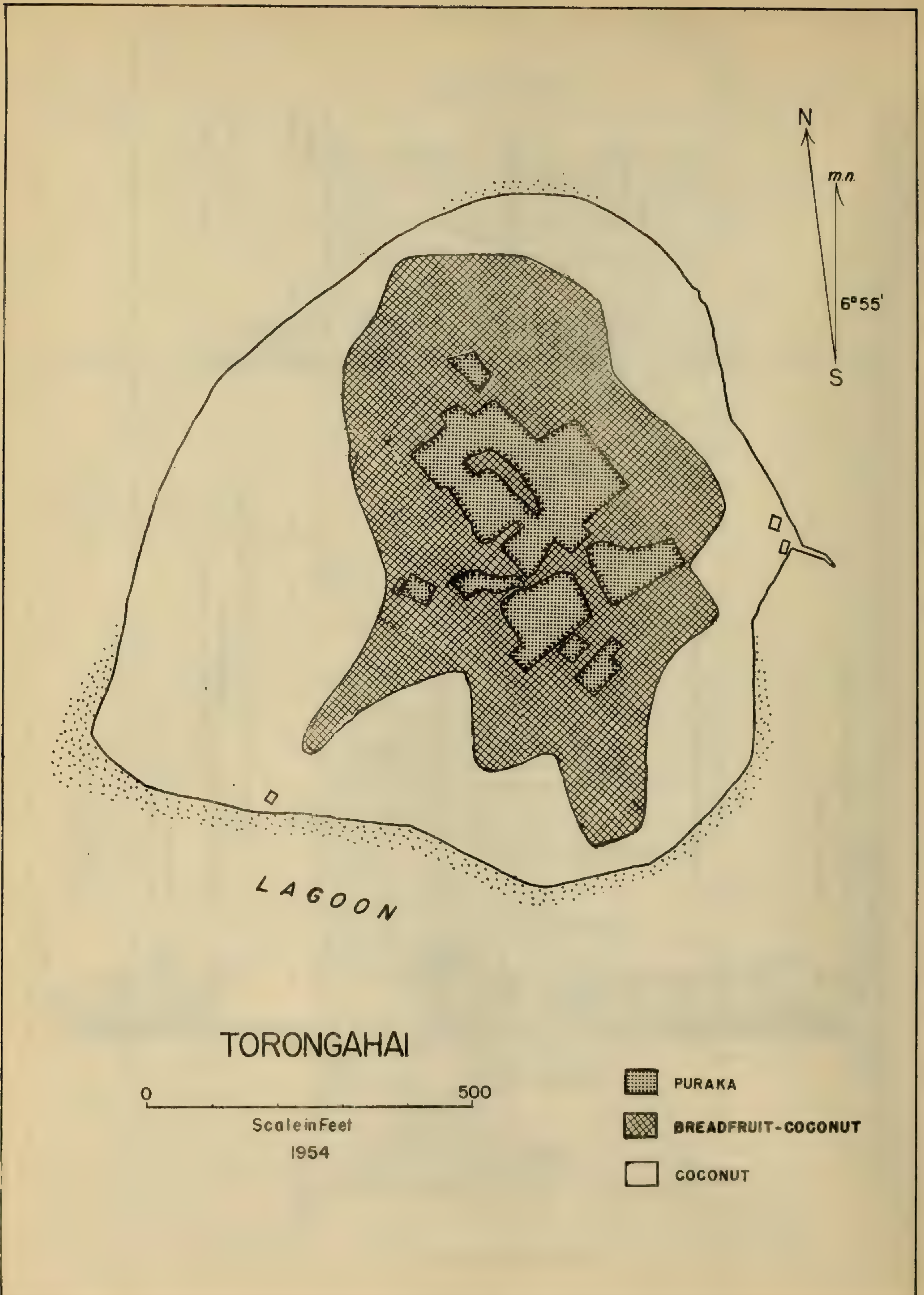

N
m.n.
6°55'
S
LAGOON
TORONGAHAI
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT-COCONUT
COCONUT

Figure 10


N
m.n.
6° 55'
S
RIKUMANU
PURAKA
BREADFRUIT - COCONUT
COCONUT
LAGOON
RINGUTORU
0
500
Scale in Feet
1954

Figure II

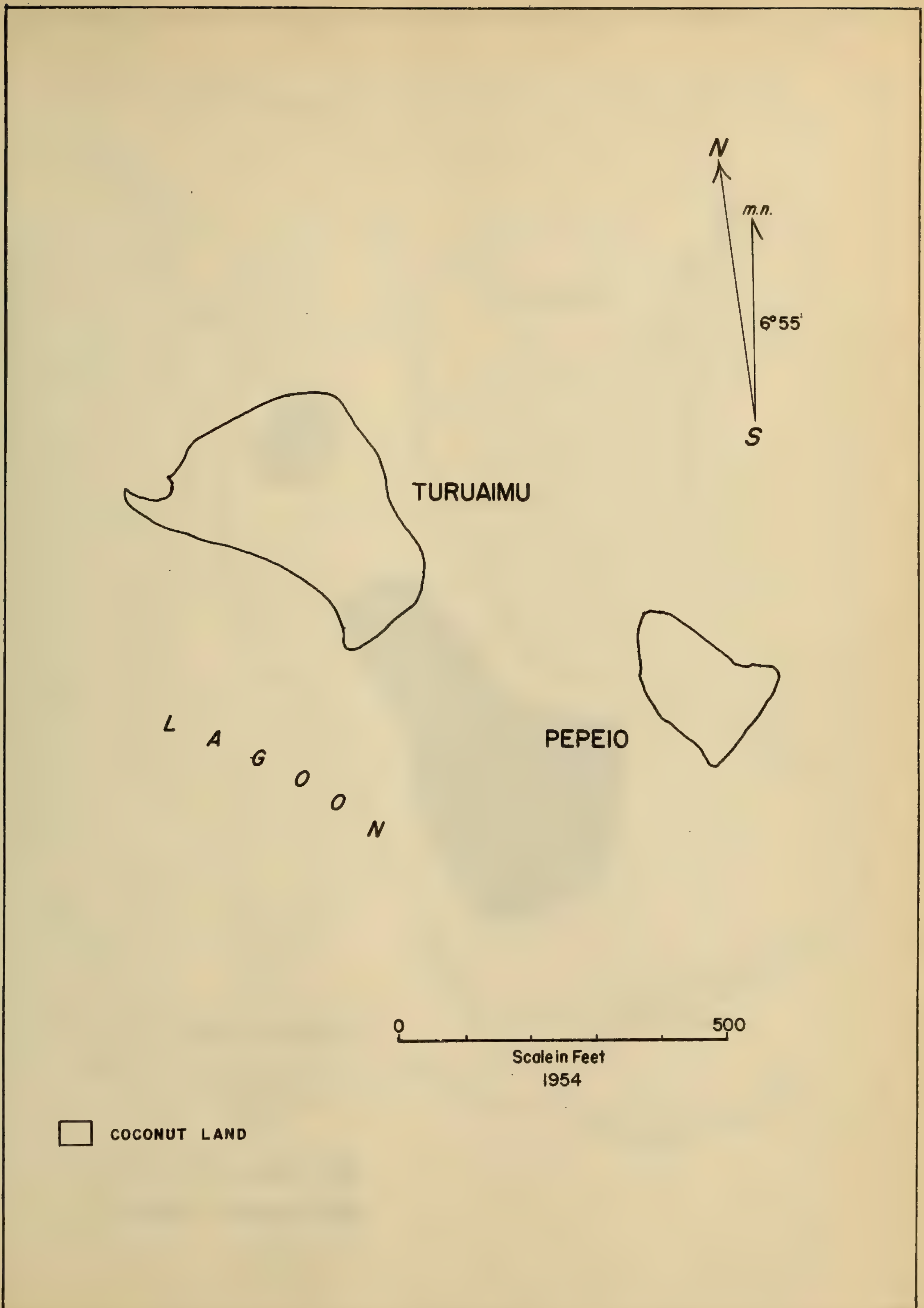

N
m.n.
6°55'
S
TURUAIMU
PEPEIO
LAGOON
0
500
Scale in Feet
1954
COCONUT LAND

Figure 12

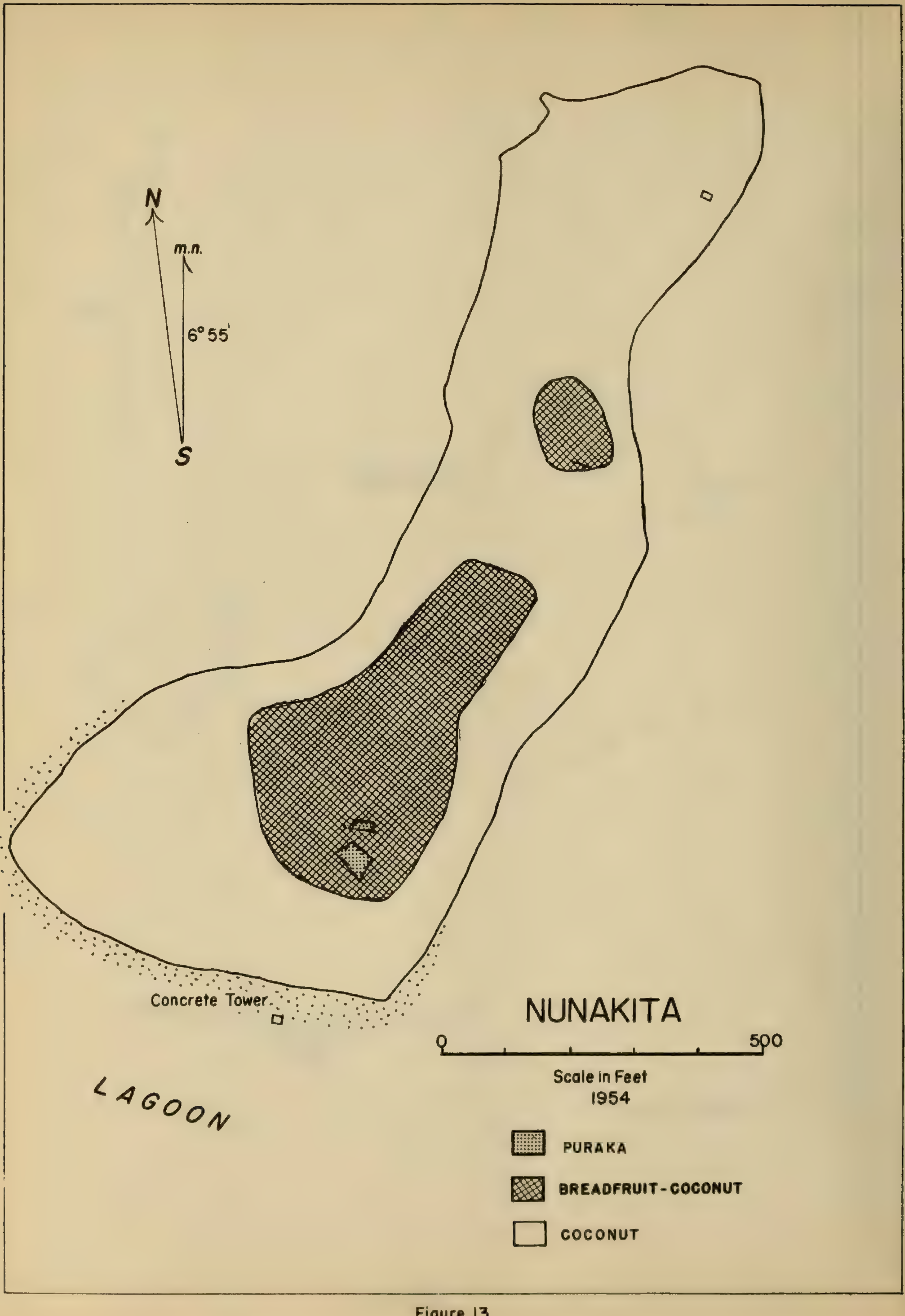

N
m.n.
6°55'
S
NUNAKITA
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT-COCONUT
COCONUT
Concrete Tower
LAGOON

Figure 13

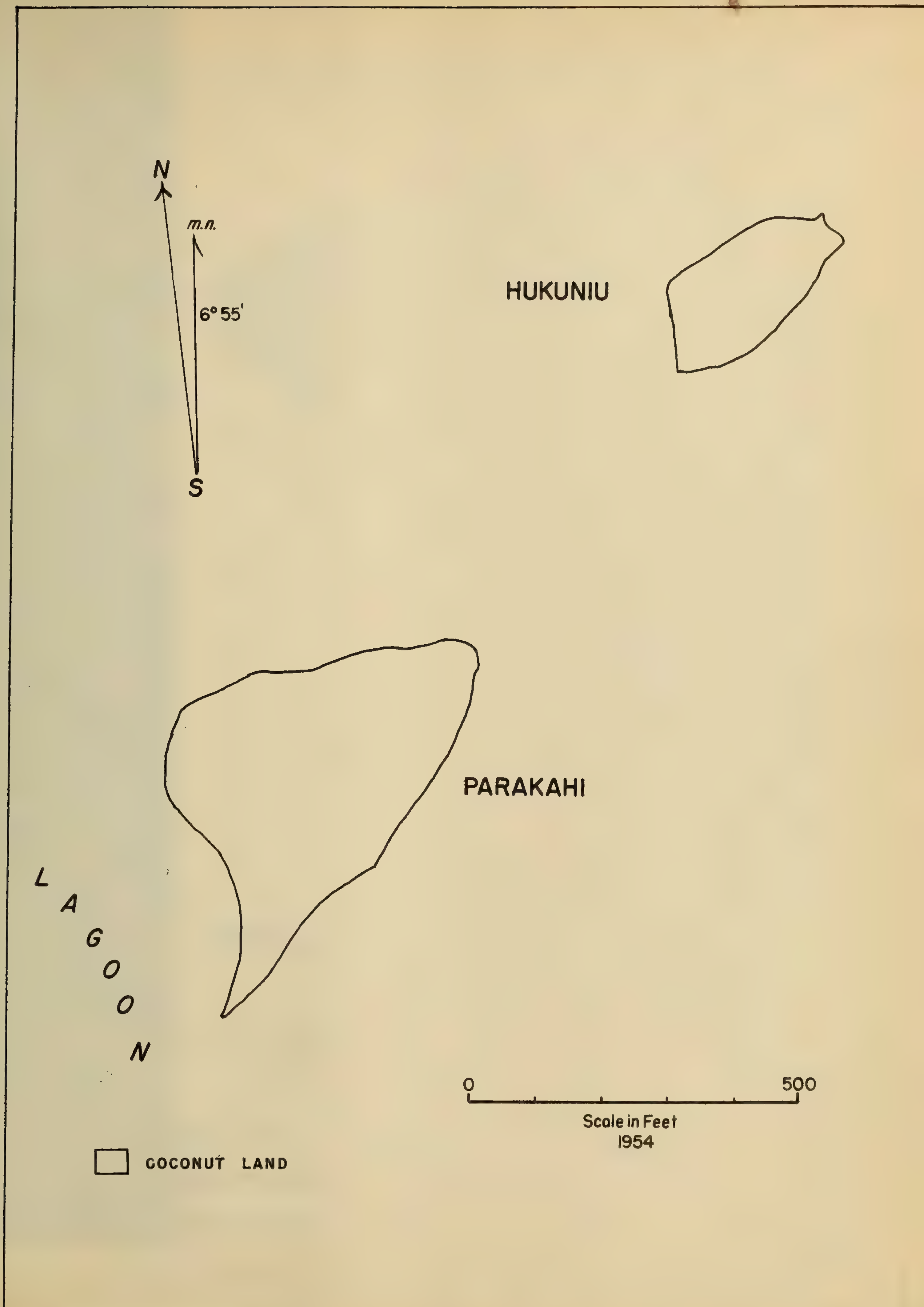
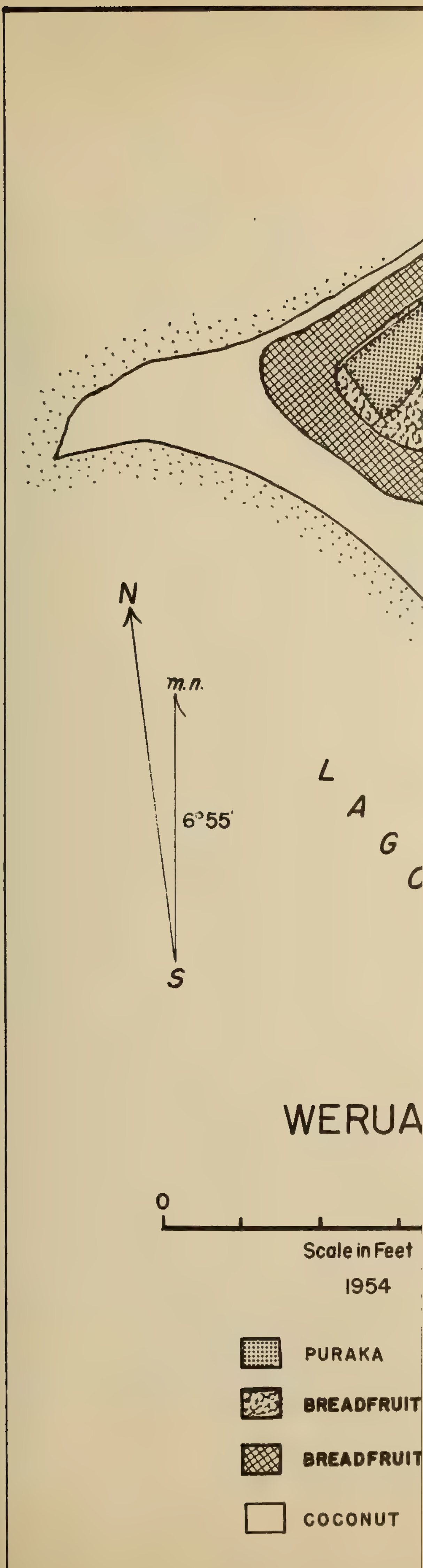

N
m.n.
6° 55'
S
HUKUNIU
PARAKAHI
L A G O O N
0
500
Scale in Feet
1954
COCONUT LAND

Figure 14


N
m.n.
6°55'
S
L
A
G
C
WERUA
0
Scale in Feet
1954
PURAKA
BREADFRUIT
BREADFRUIT
COCONUT


Ball Field
N
m.n.
6°55'
S
LAGOON
WERUA
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT
BREADFRUIT - COCONUT
COCONUT

Figure 15

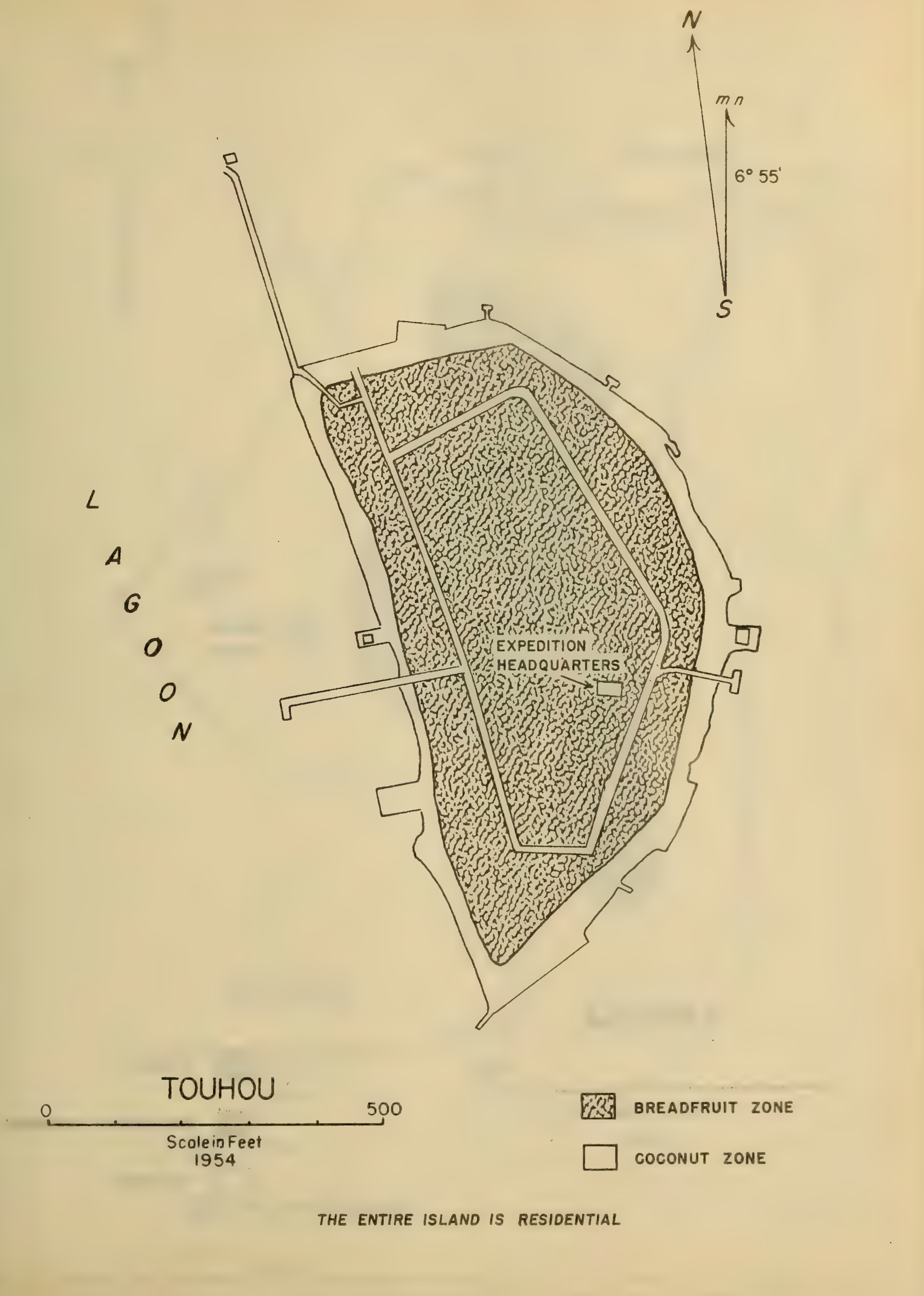

N
mn
6° 55'
S
LAGOON
EXPEDITION HEADQUARTERS
TOUHOU
0
500
Scale in Feet
1954
BREADFRUIT ZONE
COCONUT ZONE
THE ENTIRE ISLAND IS RESIDENTIAL

Figure 16

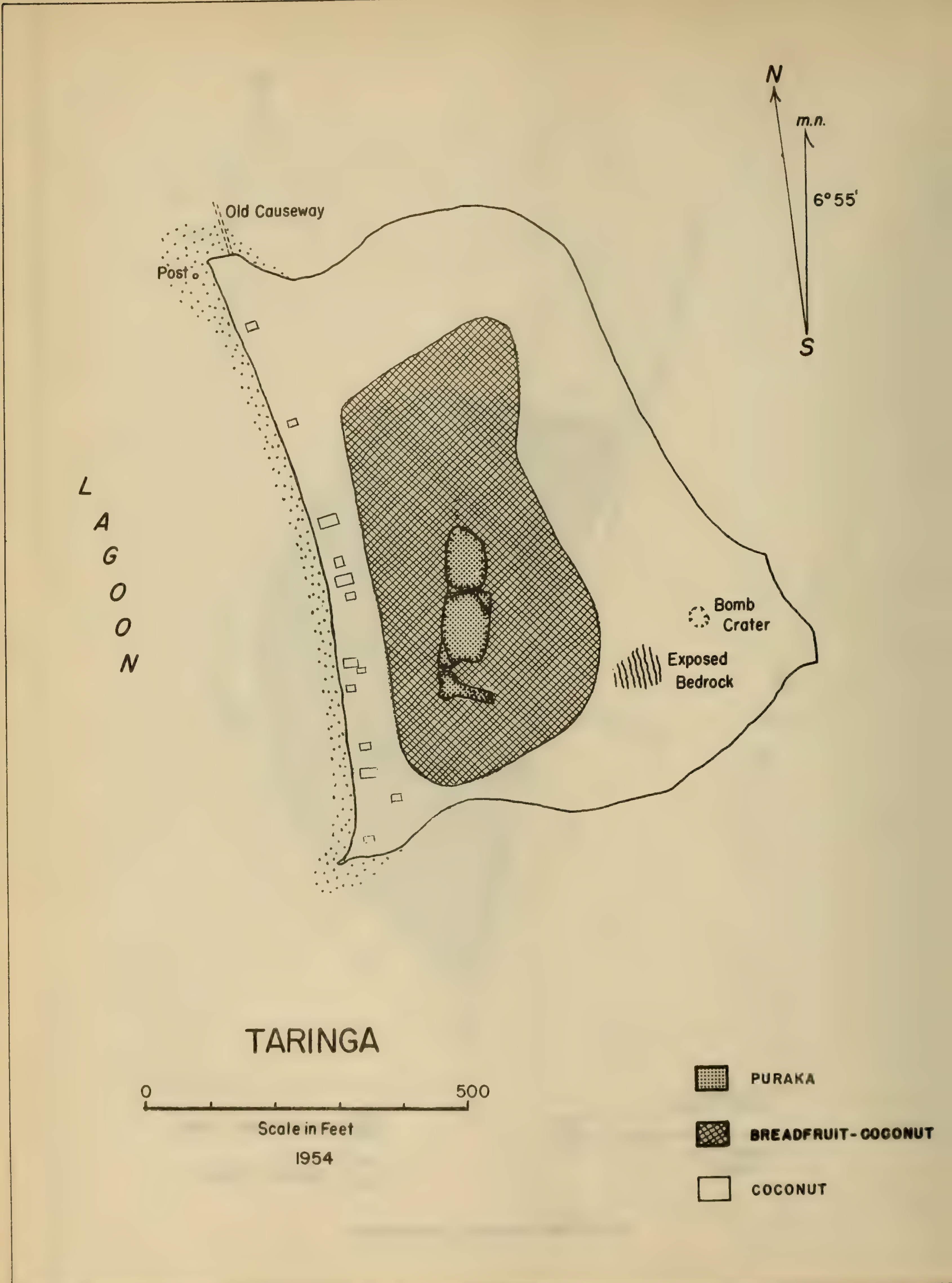

N
m.n.
6°55'
S
Old Causeway
Post
L A G O O N
Bomb Crater
Exposed Bedrock
TARINGA
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT-COCONUT
COCONUT

Figure 17

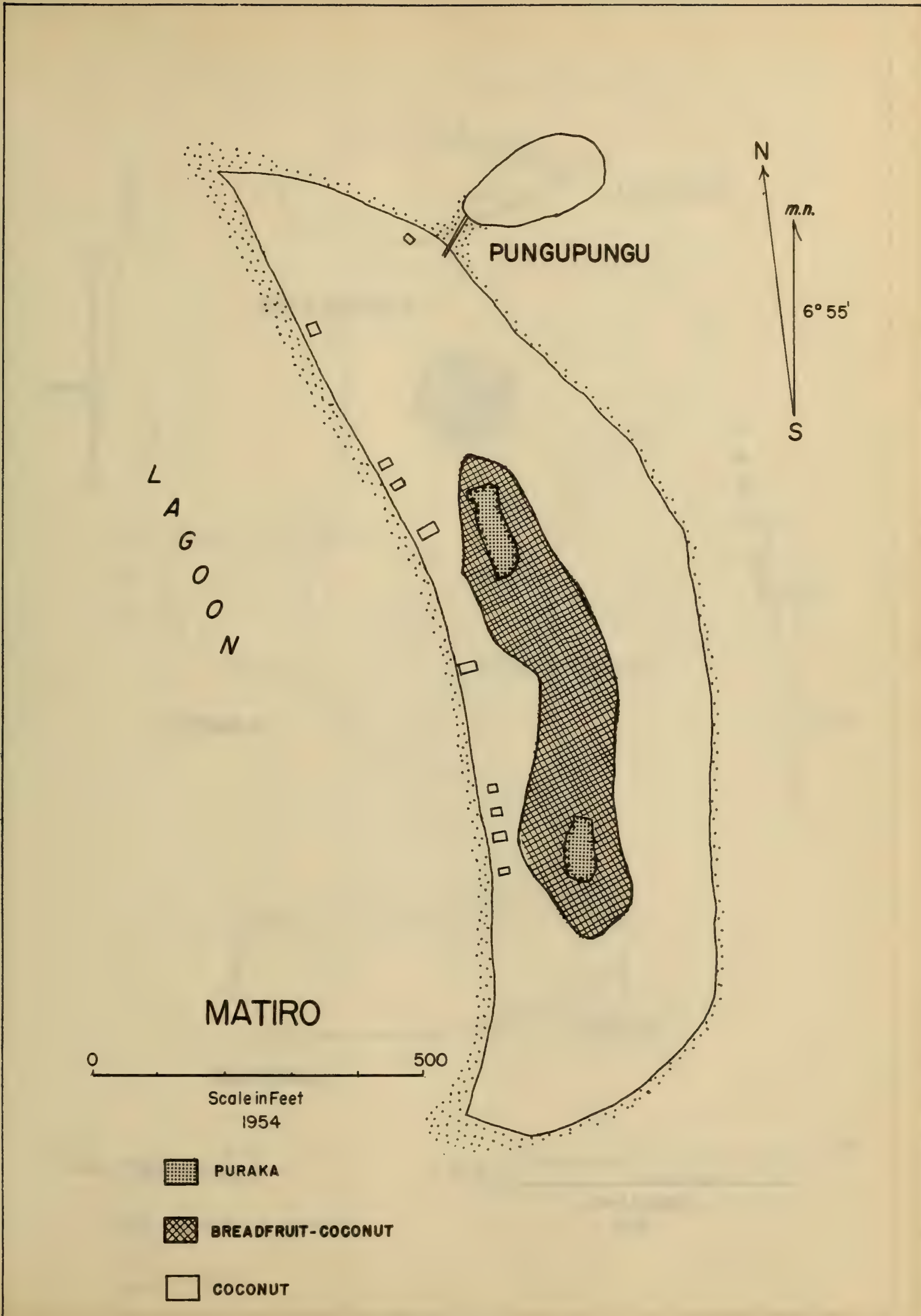

PUNGUPUNGU
N
m.n.
6° 55'
S
LAGOON
MATIRO
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT - COCONUT
COCONUT

Figure 18

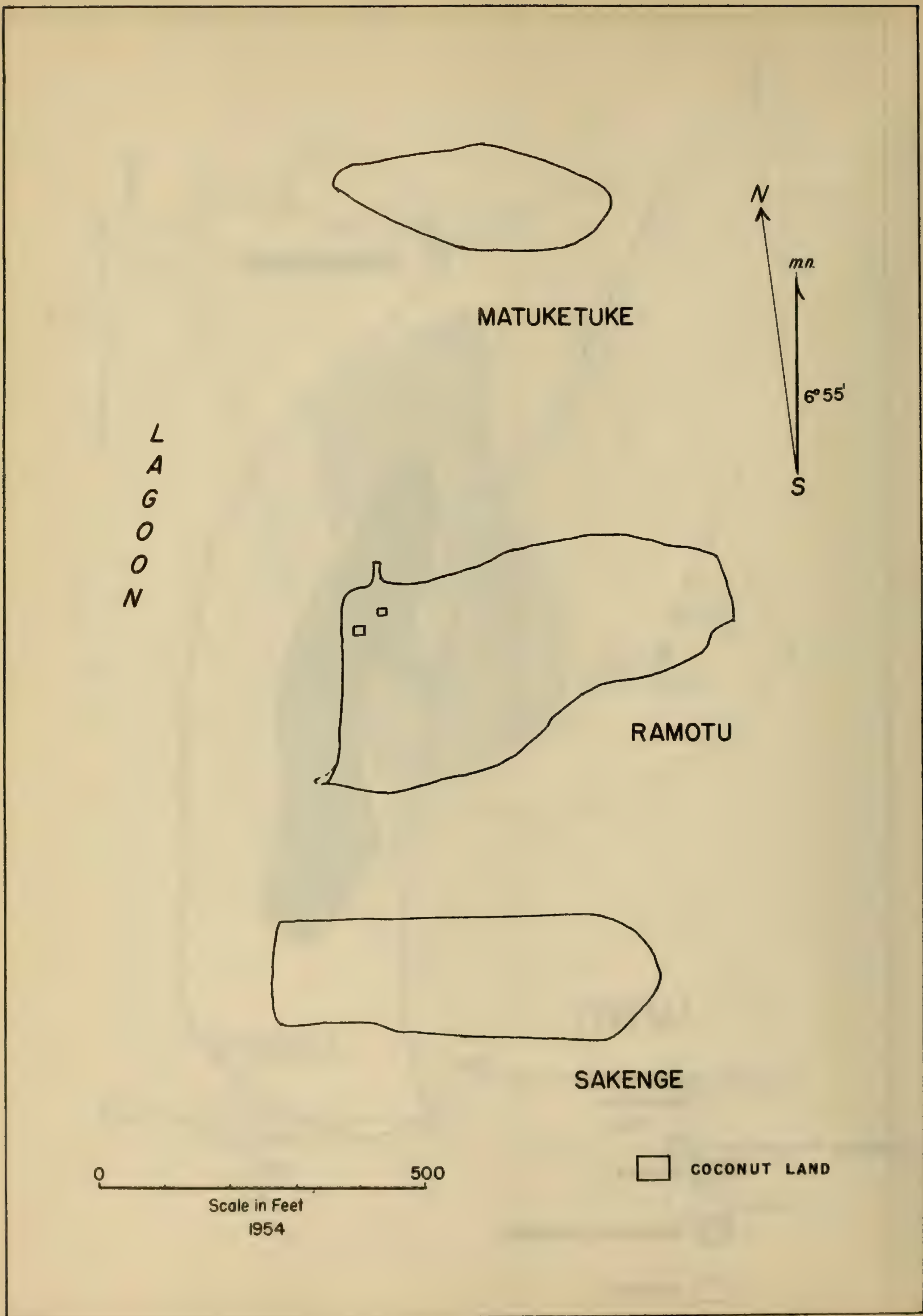

MATUKETUKE
N
mn.
6°55'
S
LAGOON
RAMOTU
SAKENGE
0
500
Scale in Feet
1954
COCONUT LAND

Figure 19

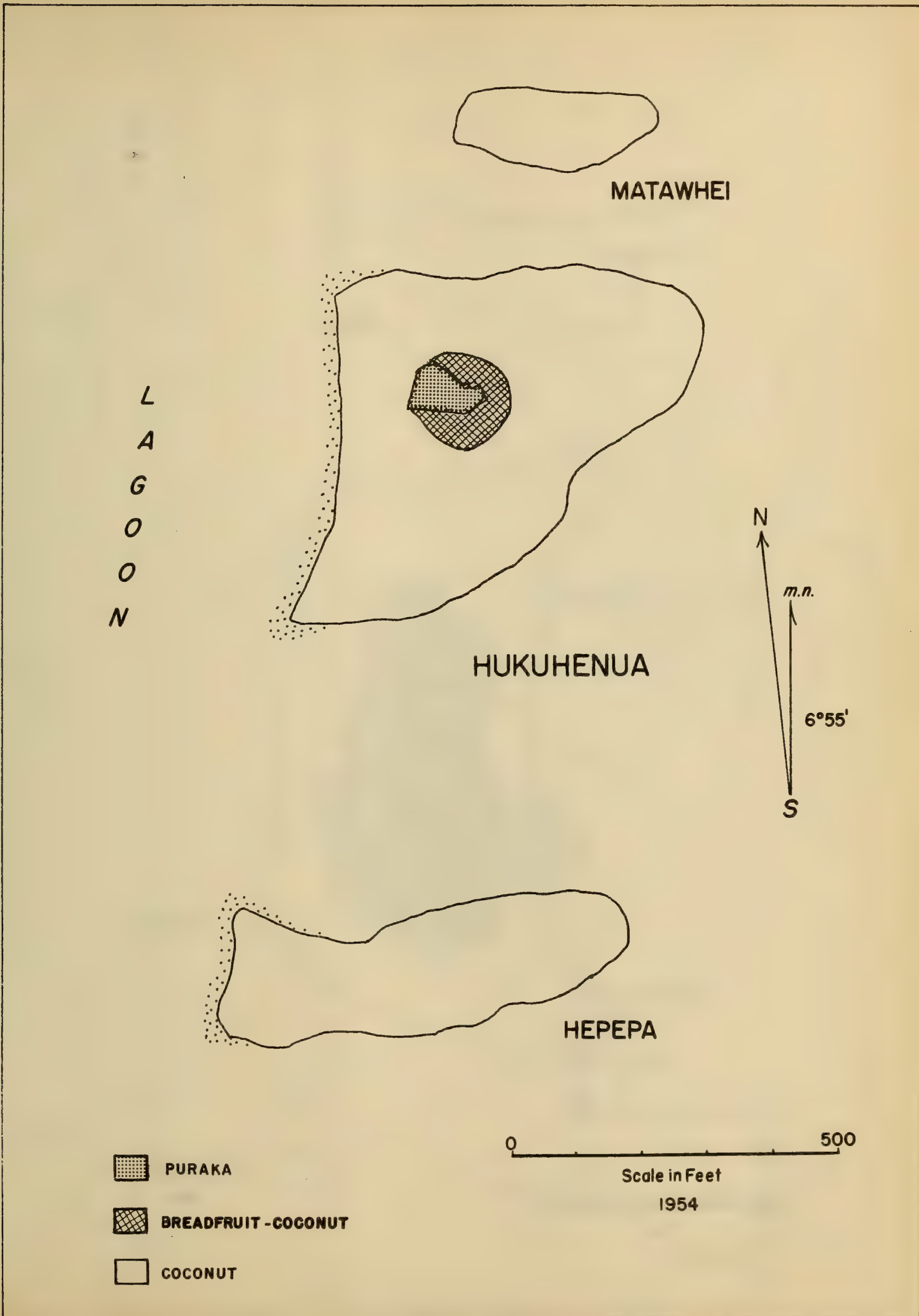

MATAWHEI
LAGOON
HUKUHENUA
N
m.n.
6°55'
S
HEPEPA
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT-COCONUT
COCONUT

Figure 20

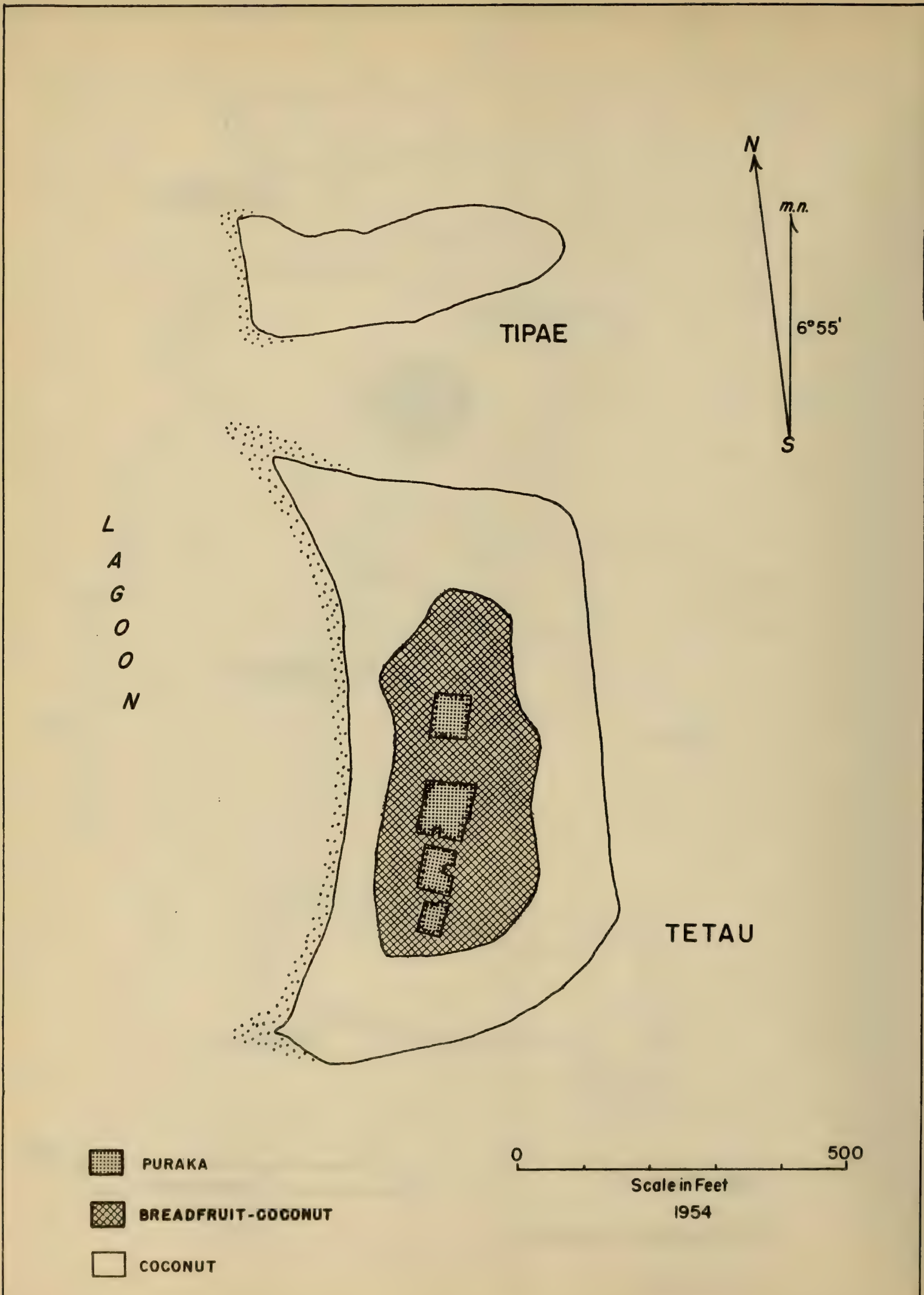

N
m.n.
6°55'
S
TIPAE
L A G O O N
TETAU
PURAKA
BREADFRUIT-COCONUT
COCONUT
0
500
Scale in Feet
1954

Figure 21

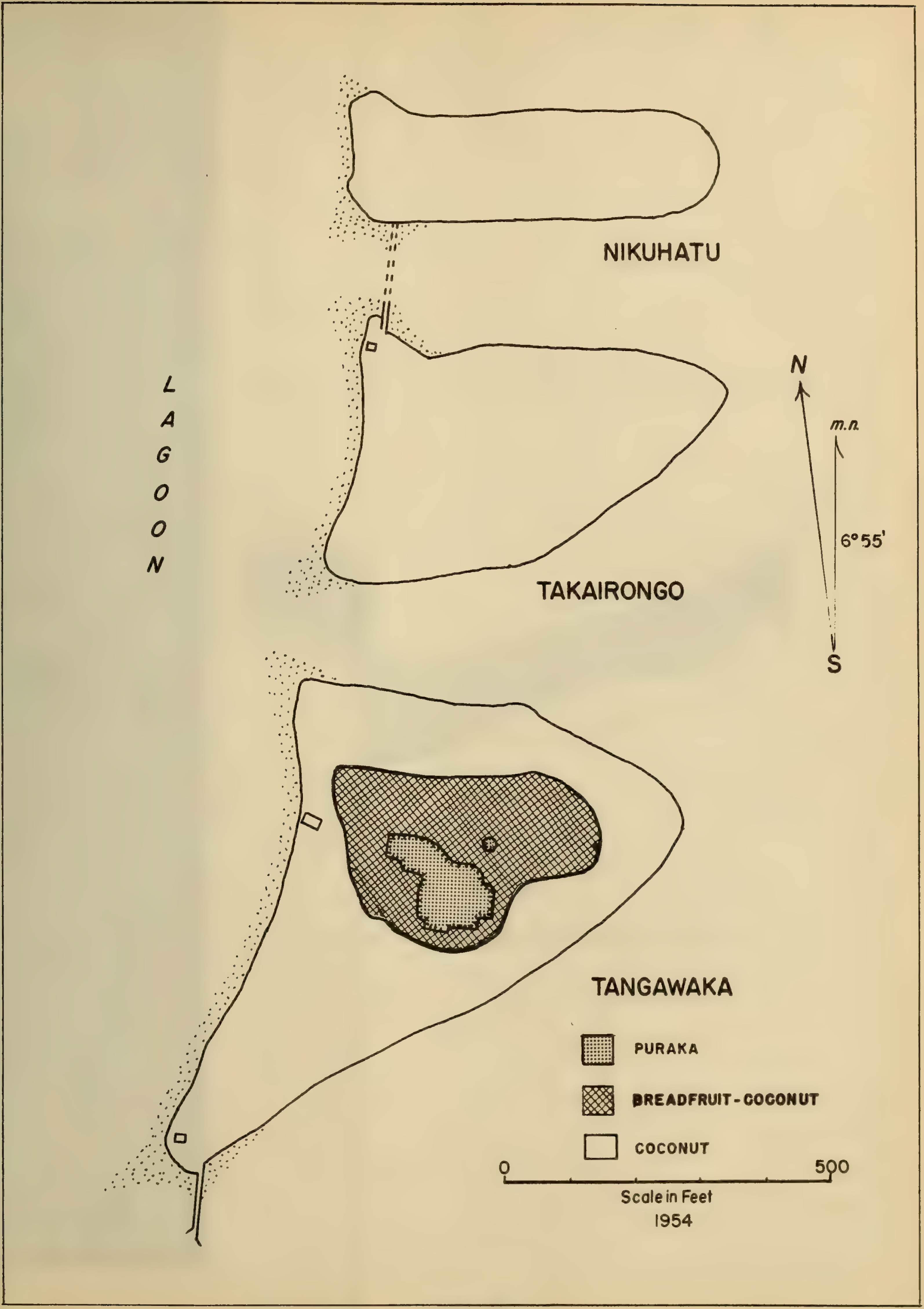
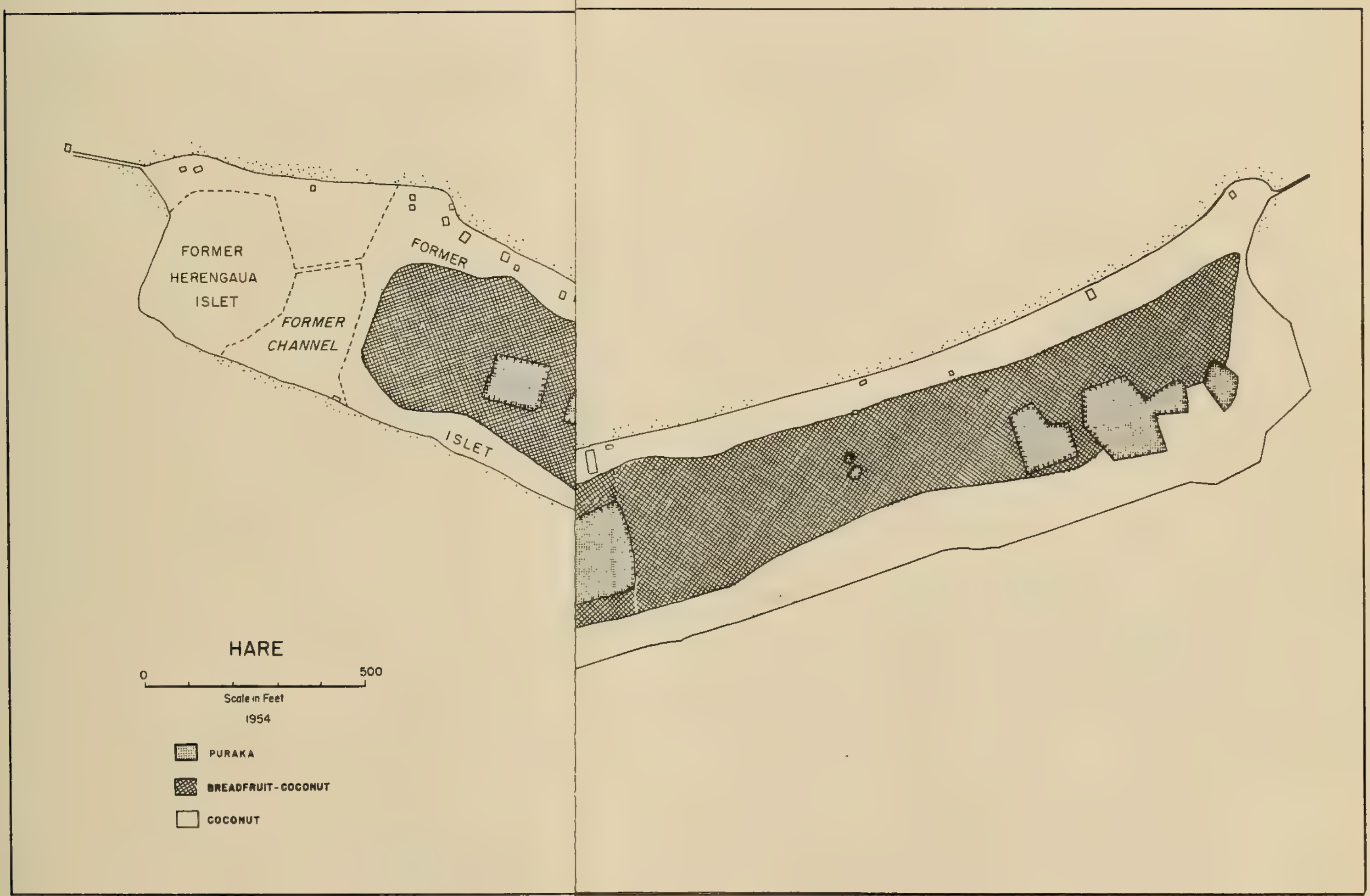

NIKUHATU
LAGOON
N
m.n.
6°55'
S
TAKAIRONGO
TANGAWAKA
PURAKA
BREADFRUIT - COCONUT
COCONUT
0
500
Scale in Feet
1954

Figure 22


FORMER
HERENGAUA
ISLET
FORMER
CHANNEL
FORMER
ISLET
HARE
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT-COCONUT
COCONUT

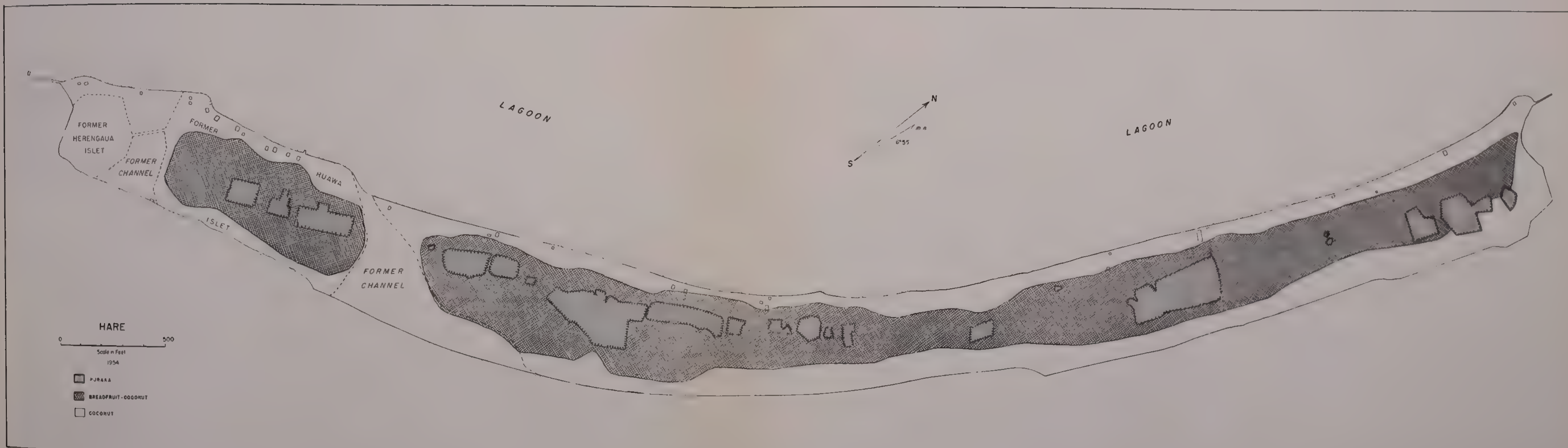

LAGOON
LAGOON
N
S
6°55
FORMER HERENGAUA ISLET
FORMER CHANNEL
FORMER HUAWA ISLET
FORMER CHANNEL
HARE
0
500
Scale in Feet
1954
PURAKA
BREADFRUIT - COCONUT
COCONUT

Figure 23

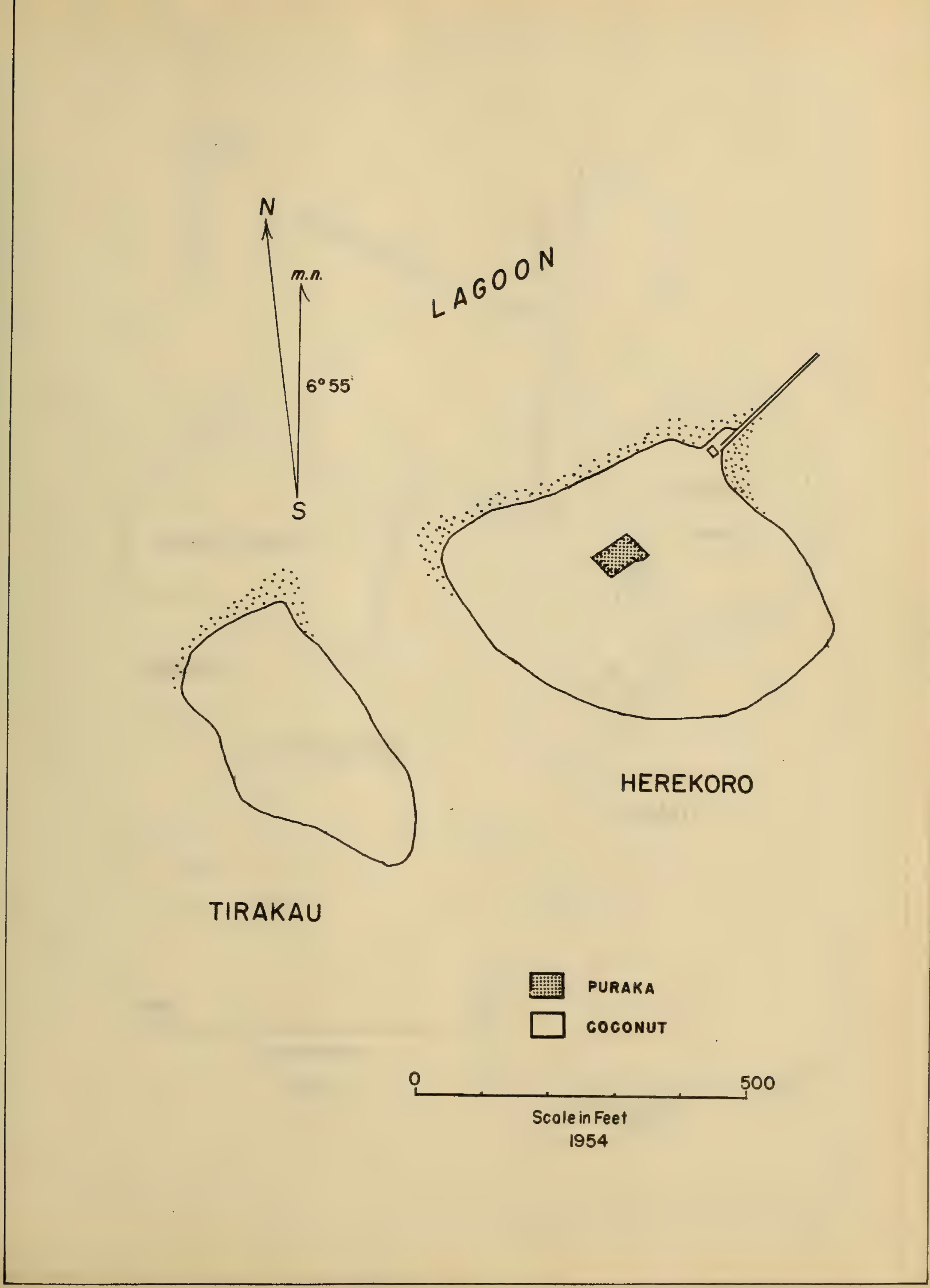

N
m.n.
6°55'
S
LAGOON
HEREKORO
TIRAKAU
PURAKA
COCONUT
0
500
Scale in Feet
1954

Figure 24

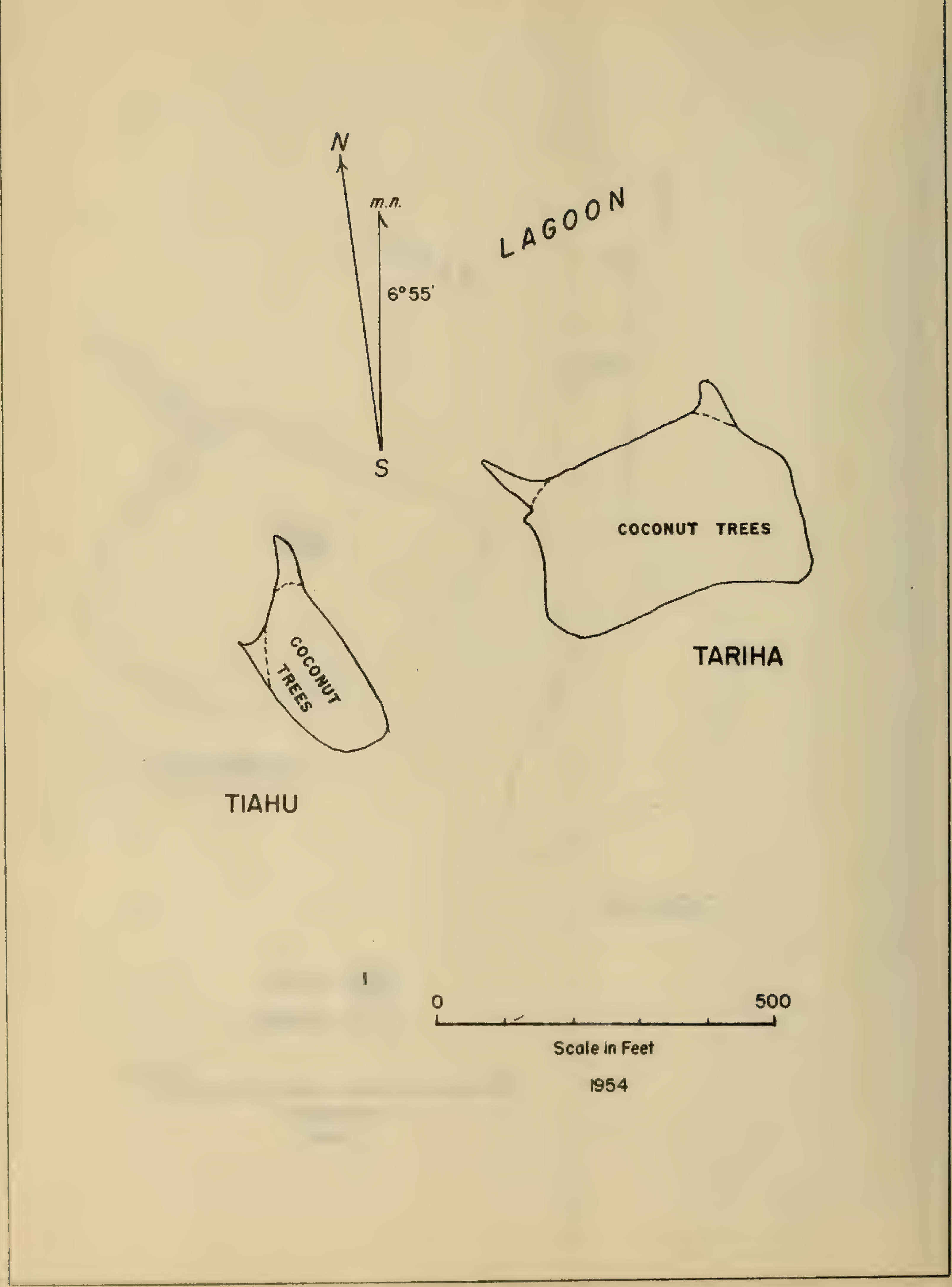

N
m.n.
6°55'
S
LAGOON
COCONUT TREES
TARIHA
COCONUT TREES
TIAHU
0
500
Scale in Feet
1954

Figure 25

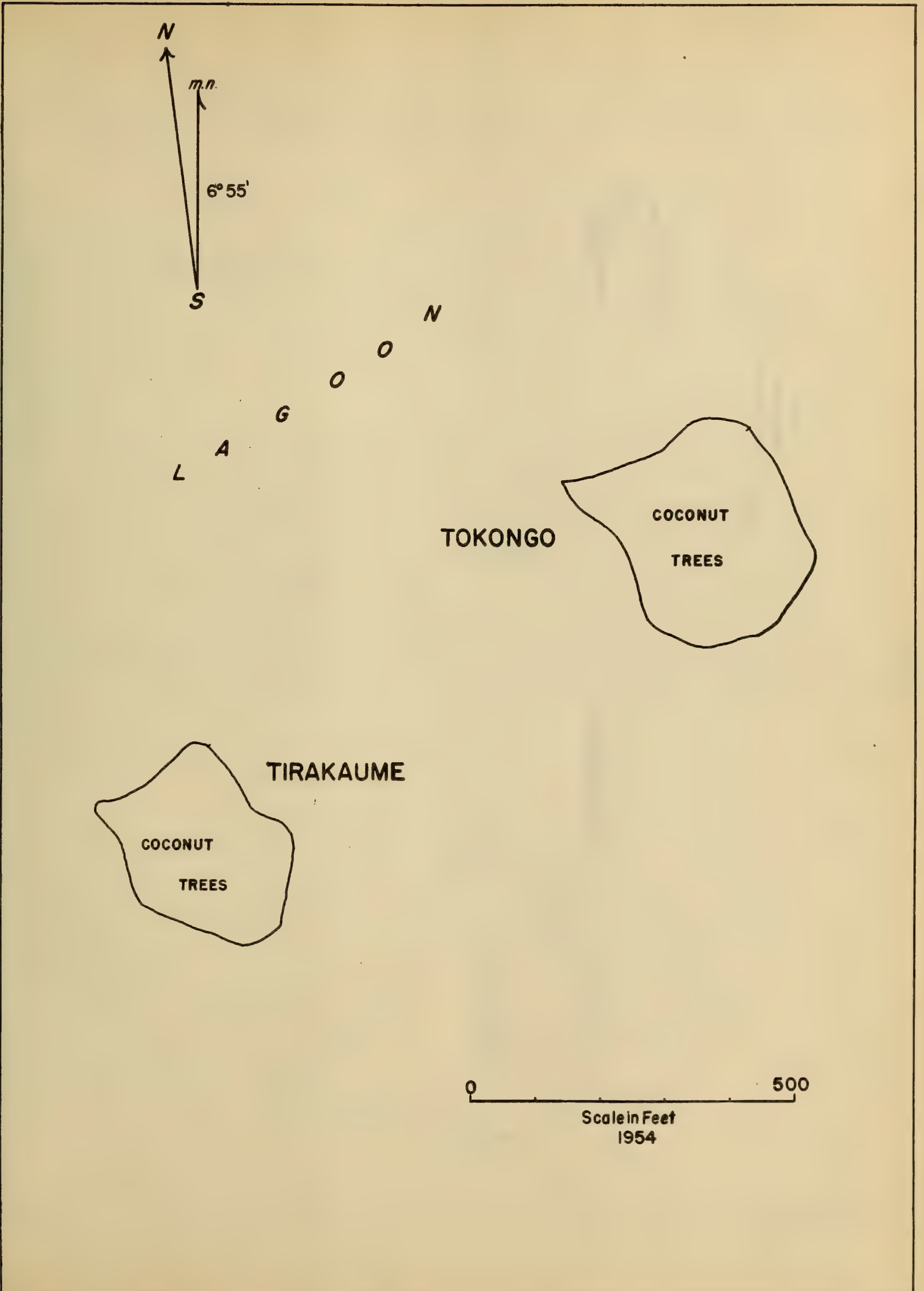

N
m.n.
6° 55'
S
LAGOON
TOKONGO
COCONUT
TREES
TIRAKAUME
COCONUT
TREES
0
500
Scale in Feet
1954

Figure 26

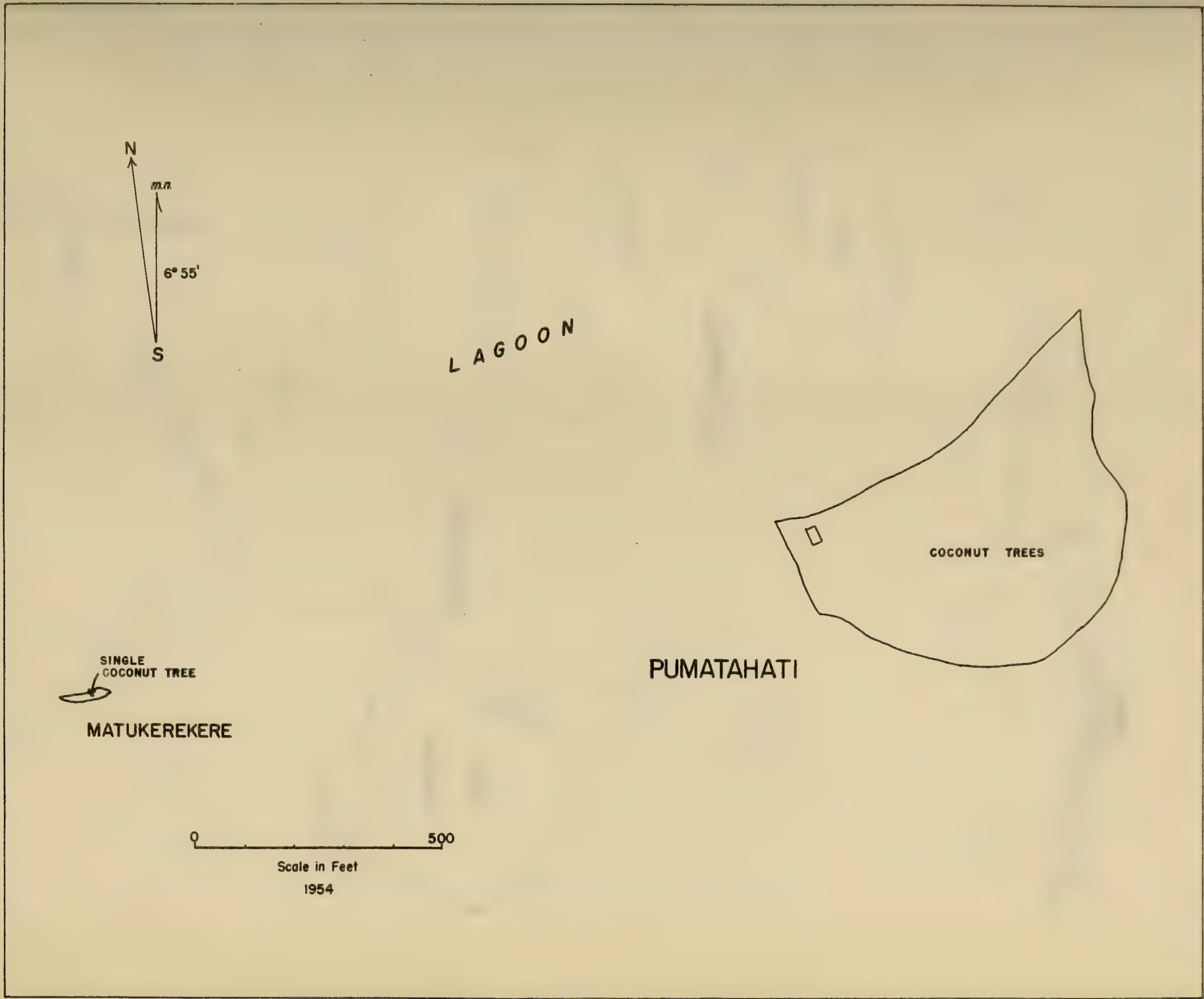

N
m.n.
6° 55'
S
LAGOON
COCONUT TREES
PUMATAHATI
SINGLE
COCONUT TREE
MATUKEREKERE
0
500
Scale in Feet
1954
Figure 27

Fig. 28 Species list of trees and shrubs. Species arranged according to frequency of occurrence on atoll. Islets arranged according to size from smallest to largest. Relative importance of each species indicated by letter: A-abundant; F-frequent; O-occasional; R-rare. Probable origin of each species also indicated by letters: I-indigenous; AI-aboriginal introduction; RI-recent introduction; D-drift seedlings not yet established as mature specimens. *Pandanus tectorius* has two sources of origin. Although *Pipturus argenteus* occurs as a tree on other atolls, here it contributed only to the shrub layer. *Scaevola frutescens* should be called *S. sericea*. The former name really applies to Atlantic species.

ISLETS

TREES	Matuker.	Pungu.	Tiahu	Mata.	Pepeio	Riku.	Hukun.	Matuket.	Tirakume	Tipae	Toko.	Tirakau	Turu.	Tariha	Niku.	Hepepa	Sake.	Para.	Ramotu	Here.	Taka.	Hukuh.	Puma.	Tang.	Tetau	Touhou	Matiro	Taringa	Nuna.	Toro.	Ring.	Werua	Hare	% freq.	Origin
Cocos nucifera	O	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	F	A	A	A	A	A	A	A	100	AI
Guettarda speciosa		A	F	O	O	O	F	F	O	F	O	O	A	O	A	A	A	A	F	F	F	F	O	F	F	R	F	F	F	F	F	F	F	97	I
Morinda citrifolia		O	O	O	O	O	O	O	O	O	A	O	O	O	O	O	O	O	F	A	F	F	O	A	A	O	A	A	A	A	A	A	A	97	AI
Premna obtusifolia		R	O	O	O	O	O	O	O	O	O	O	O	O	O	F	O	O	A	A	A	A	A	A	A	O	A	A	A	A	A	A	A	97	I
Pandanus tectorius	R	O		F	O	O	O	F	O	O	O	O	O	O	O	O	O	O	F	F	R	F	O	O	O	A	A	F	F	F	F	A	F	97	I-AI
Barringtonia asiatica	R		R		R			R	R	R	R		R	R				R			R	R		R	R		R	R	R	R	R	R	R	63	I
Calophyllum inophyllum	R				R		R											R	R	R	R	R		R		R	O	O	R	O	O	O	O	51	AI
Hibiscus tiliaceus	R					R				R							R	R		R	R	O		R	O		O	F	O		O	O	O	48	AI
Cordia subcordata				R		R							R	R	R			R	R	R		R	F			R			O	F	O		R	45	I
Artocarpus altilis											R									R	R	O		F	F	F	F	F	F	A	A	A	A	42	AI
Messerschmidia argentea				O							O		O					R		R			O		R		R	R	O	O	O		O	39	I
Terminalia samoensis			O				R			R				R	R						R		O					R		R				27	I
Hernandia sonora											R							R				R					R	R		R		R	R	24	I
Cerbera manghas																						R					R	R		R	R			15	RI
Pisonia grandis																							O			O				O	O		O	15	I
Terminalia catappa							R																R				R					R	O	15	AI
Carica papaya																										O					O	R	R	12	RI
Thespesia populnea																											R		R			R	R	12	I
Intsia bijuga																		R					R					R			R			12	D
Erythrina variegata																													R			R	R	9	RI
Pandanus dubius																							R									R		6	AI
Plumeria rubra																										O						O		6	RI
Ochrosia oppositifolia																											O		R					6	I
Adenanthera pavonina																										R								3	RI
Barringtonia racemosa																													R					3	D
Kleinhovia hospita																															R			3	D
Pemphis acidula																												R						3	RI
Pongamia pinnata																															R			3	I
Soulamea amara																													O					3	I
SHRUBS																																			
Scaevola frutescens		F	F	R	F	A	F	O	R	F	F	O	F	F	F	F	F	F	F	O	F	F	F	F	F	O	F	F	F	F	F	F	F	97	I
Allophylus timorensis			R	R		R			R	R	R			R	R						O	R	O		R									36	I
Clerodendrum inerme									F	R							R				R			R	R	R		R		O	O	O		33	I
Pipturus argenteus											R											R	O	R			R			R	R	R	O	27	I
Hibiscus sp.																										O	R			O		O	R	15	RI
Polyscias fruticosa																								R				O				O	O	12	RI
Caesalpinia bonduc																								R							R		R	9	I
Polyscias scutellaria																										F						F		6	RI
Sophora tomentosa																											R				R			6	I
Capsicum frutescens																										R						R		6	RI
Codiaeum variegatum																												O				O		6	RI
Vitex negundo																										R						R		6	RI
Cassia alata																						R						R						6	RI
Tabernaemontana divaricata																																R		3	RI

FIG. 28

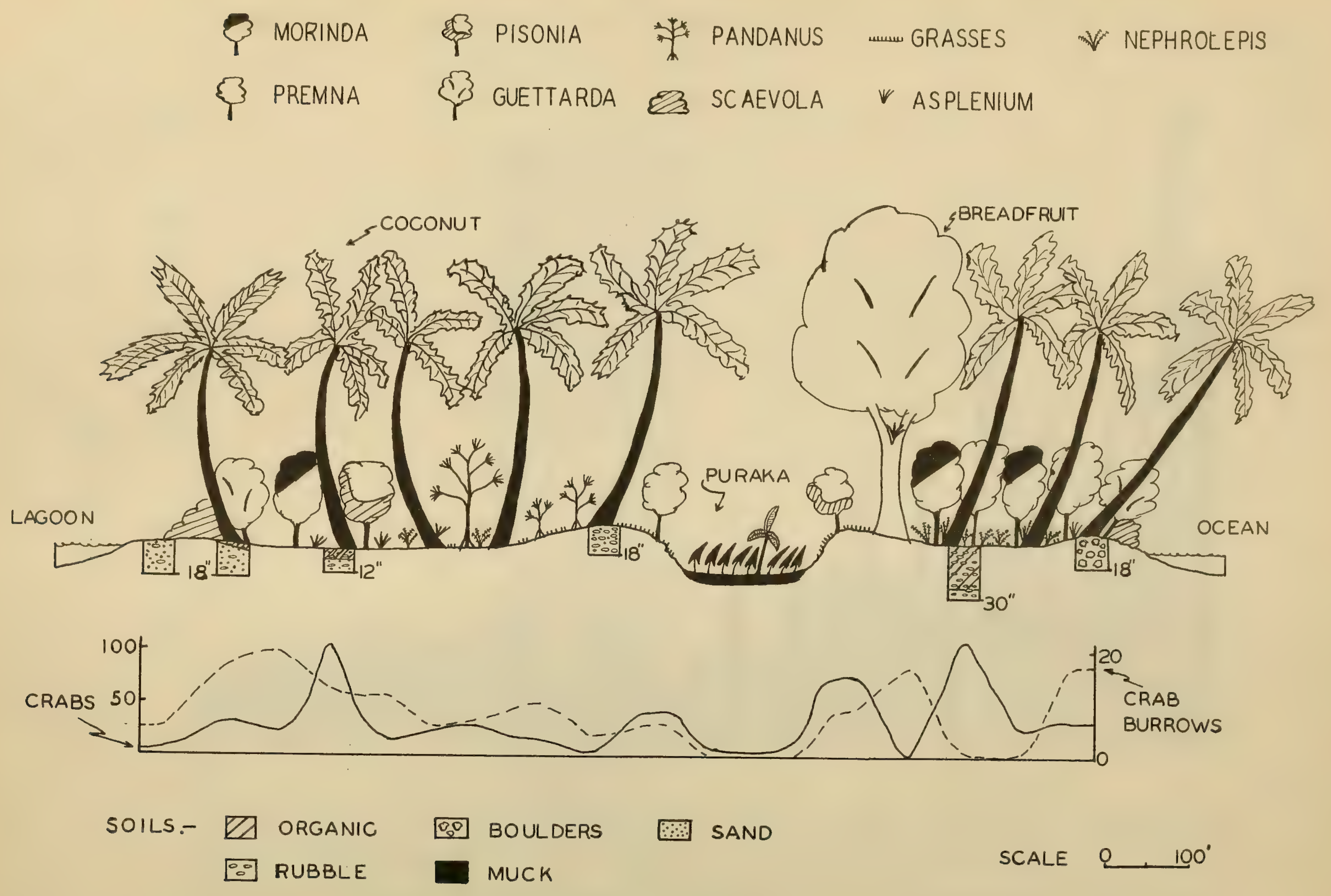
Fig 29 Species list of herbs. See Fig. 28 for explanation.

ISLETS

HERBS	Matuker.	Pungu.	Tiahu	Mata.	Pepeio	Riku	Hukun.	Matuket.	Tirakume	Tipae	Toko.	Tirakau	Turu.	Tariha	Niku.	Hepepa	Sake.	Para.	Ramotu	Here.	Taka.	Hukuh.	Puma	Tang.	Tetau	Touhou	Matiro	Taringa	Nuna.	Toro.	Ring.	Werua	Hare	% freq.	Origin
Asplenium nidus						R		R	R		O	R		R						F	F	O	F	F	F		F		F	A	A	F	O	54	I
Tacca leontopetaloides		R		R													R		R	F	O	F		F		R	F	F			O		O	39	AI
Lepturus repens													R		R					O				O	O	O	O	O	F	O	O		O	36	I
Stenotaphrum micranthum															R					F	O			F	F		F	F	F	F	F	F	F	36	I
Thuarea involuta																				F	O			F	F		F	F	F	F	F	F	F	33	I
Cyrtosperma chamissonis																					R	F		F	F		F	F	R	A	A	A	A	33	AI
Crinum sp.							R	R										R				O				F	R	R		O		R	R	30	AI-RI
Fimbristylis spathacea																								O		R	O	O		O		O	O	21	I
Musa nana																						R		R			O	O		O	O	O		21	RI
Vigna marina																		R				O		F	O		O					O	A	21	I
Cassytha filiformis					O	R							A					O											O	O				18	I
Triumfetta procumbens													A						R								R		O	R	O			18	I
Fleurya ruderalis																										R					O	O	O	12	I
Hemigraphis reptans																										R	O		R			O		12	RI
Ipomoea pes-caprae																						R		O								R	O	12	I
Ipomoea littoralis																								R	R							R	O	12	I
Hedychium coronarium																											R	R				O		9	RI
Canavalia microcarpa																														R	R		R	9	I
Eleusine indica																										R						O	R	9	RI
Nephrolepis hirsutula																														A	A	F		9	I
Polypodium scolopendria																														R	R		R	9	I
Wedelia biflora																														O		O	A	9	I
Zephyranthes rosea																										O		O				O		9	RI
Digitaria microbachne																										R						O		6	AI
Eragrostis amabilis																										R						R		6	RI
Euphorbia chamissonis																										R							R	6	I
Fimbristylis miliacea																																O	O	6	RI
Ipomoea tuba																													R			O		6	I
Jussiaea suffruticosa																																A	A	6	AI
Mucuna gigantea																																R	R	6	D
Musa sapientum																										O					F			6	RI
Pteris tripartita																																R	R	6	I
Vernonia cinerea																												O				O		6	RI
Achyranthes aspera																															R			3	RI
Adenostemma lavenia																																R		3	RI
Alocasia macrorrhiza																										R								3	AI
Alternanthera sessilis																																O		3	RI
Angelonia angustifolia																																O		3	RI
Asclepias curassavica																										R								3	RI
Blechum brownei																																O		3	RI
Colocasia esculenta																																R		3	AI
Cucurbita sp.																																	R	3	RI
Cymbopogon nardus																																R		3	RI
Cyperus brevifolius																																R		3	RI
Eclipta alba																										R								3	RI
Gomphrena globosa																										R								3	RI
Lindernia antipoda																																O		3	RI
Ocimum sanctum																										O								3	AI
Panicum ambiguum																												O						3	RI
Paspalum vaginatum																																R		3	RI
Phyllanthus niruri																										R								3	RI
Portulaca oleracea																										R								3	RI
Psilotum nudum																																R		3	I
Saccharum officinarum																										R								3	RI
Dioscorea sp.																						R												3	RI

FIG. 29

Fig. 30 Diagrammatic representation of the vegetation, soils, and crab population on Torongahai. Reconstructed on the basis of strip transect 52 ft. in width from the southwest lagoon back shore to the northeast beach ridge oceanward (see Fig. 10). Most luxuriant development of the vegetation occurs oceanward in the highly organic rubble soil. On the puraka banks, pandanus and grass cover are most conspicuous. In the diagram, banana is shown as associate with the puraka. *Guettarda* and *Scaevola* are the typical marginal species. The soils show a gradual decrease in organic development lagoonward. In the line graph the right scale (0-20) refers to number of crab burrows and left scale (0-100) to actual number of crabs found in the 52 by 52 ft. quadrats along the transect. Scale at lower right (0-100 ft.) is applicable to horizontal axis only.



MORINDA
PISONIA
PANDANUS
GRASSES
NEPHROLEPIS
PREMNA
GUETTARDA
SCAEVOLA
ASPLENIUM
COCONUT
BREADFRUIT
PURAKA
LAGOON
OCEAN
18"
12"
18"
30"
18"
100
50
CRABS
20
0
CRAB BURROWS
SOILS.—
ORGANIC
BOULDERS
SAND
RUBBLE
MUCK
SCALE 0 100'

FIG.30

Fig. 31 Bar graph showing number of species found on each islet and presumed origin. Solid bar refers to the total vascular flora with adjacent bar divided according to the origin of these species. Note continuous increase in number of species on islets over 3.5 acres. On the most densely inhabited islets, Touhou and Werua, recent introductions are most common. Numbers adjacent the islets refer to islet size in acres. See Fig. 28 for further explanation.

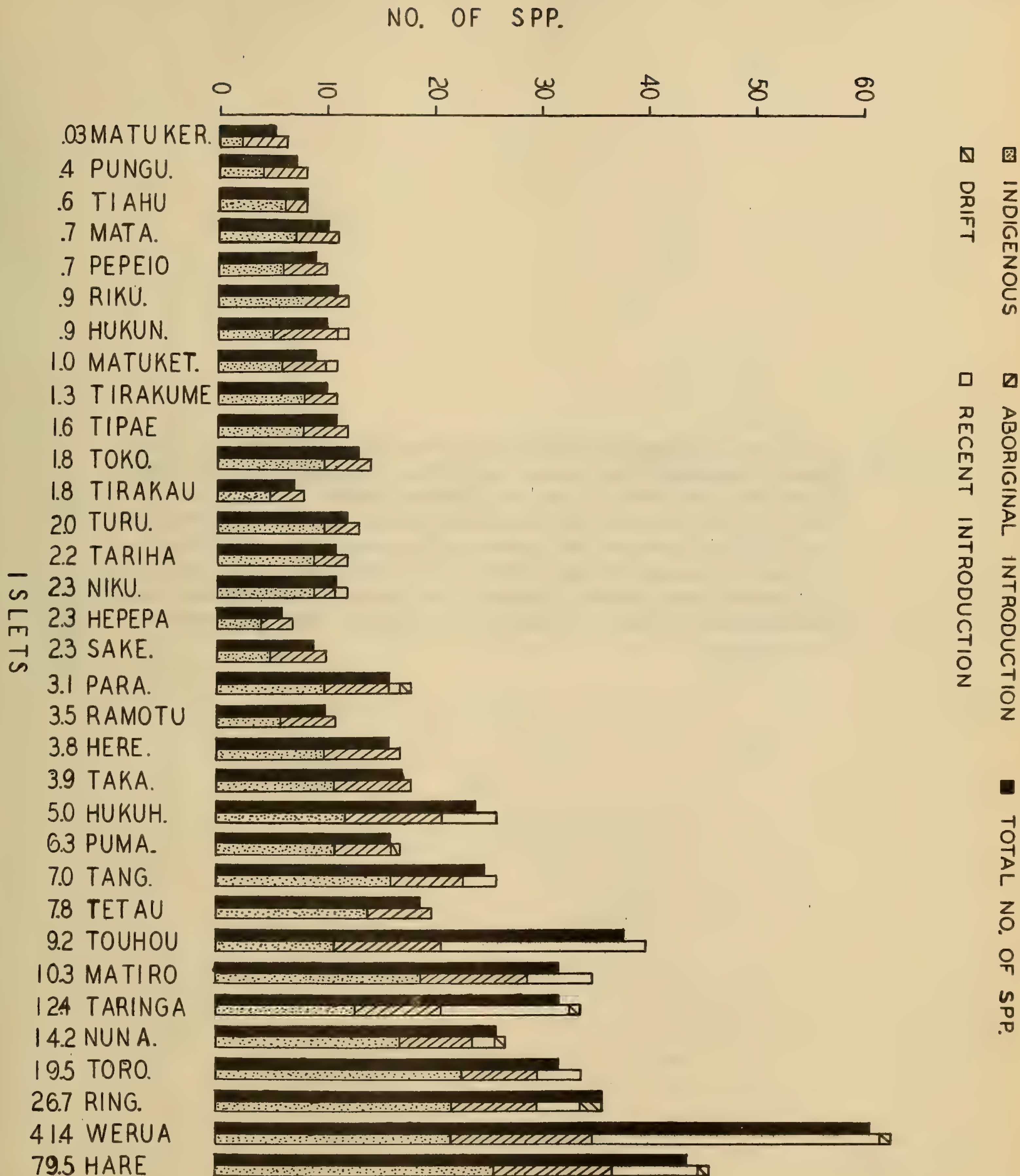

NO. OF SPP.
0
10
20
30
40
50
60
INDIGENOUS
DRIFT
ABORIGINAL INTRODUCTION
RECENT INTRODUCTION
TOTAL NO. OF SPP.
ISLETS
.03 MATU KER.
.4 PUNGU.
.6 TIAHU
.7 MATA.
.7 PEPEIO
.9 RIKU.
.9 HUKUN.
1.0 MATUKET.
1.3 TIRAKUME
1.6 TIPAE
1.8 TOKO.
1.8 TIRAKAU
2.0 TURU.
2.2 TARIHA
2.3 NIKU.
2.3 HEPEPA
2.3 SAKE.
3.1 PARA.
3.5 RAMOTU
3.8 HERE.
3.9 TAKA.
5.0 HUKUH.
6.3 PUMA.
7.0 TANG.
7.8 TETAU
9.2 TOUHOU
10.3 MATIRO
12.4 TARINGA
14.2 NUNA.
19.5 TORO.
26.7 RING.
41.4 WERUA
79.5 HARE

FIG. 31

Fig. 32 Line graph showing number of species plotted against islet size. Although the islets vary from .03 of an acre to 79.5 acres the smallest islet was deleted since plotting was facilitated and no change in the relationship occurred.(See Fig. 31). Note the two linear relationships. On those islets 3.5 acres or less there is little variation in number of species per islet. However, on those larger there is a continuous increase in number of species with increase in islet size.

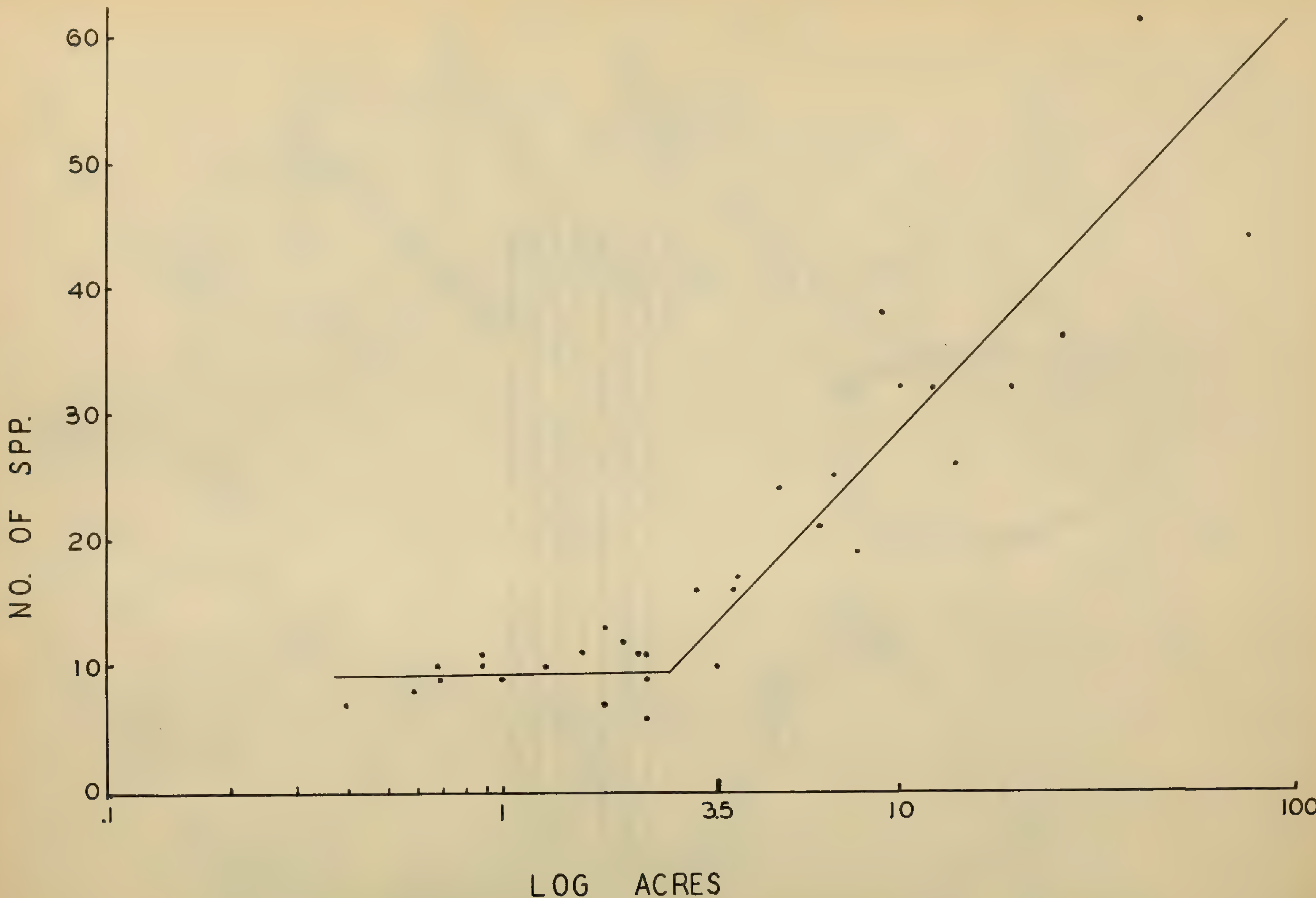


FIG. 32

Fig. 33 Diagrammatic representation of the marginal vegetation on beach ridges and lagoon shore, including sand bars, of the smaller islets. Guettarda speciosa and Scaevola sericea dominate. However, the latter is usually less abundant on the windward side. Its occurrence oceanward is apparently correlated with the protection of elevated off shore reef rock. Lagoonward Scaevola is a conspicuous pioneer on the sand bars.

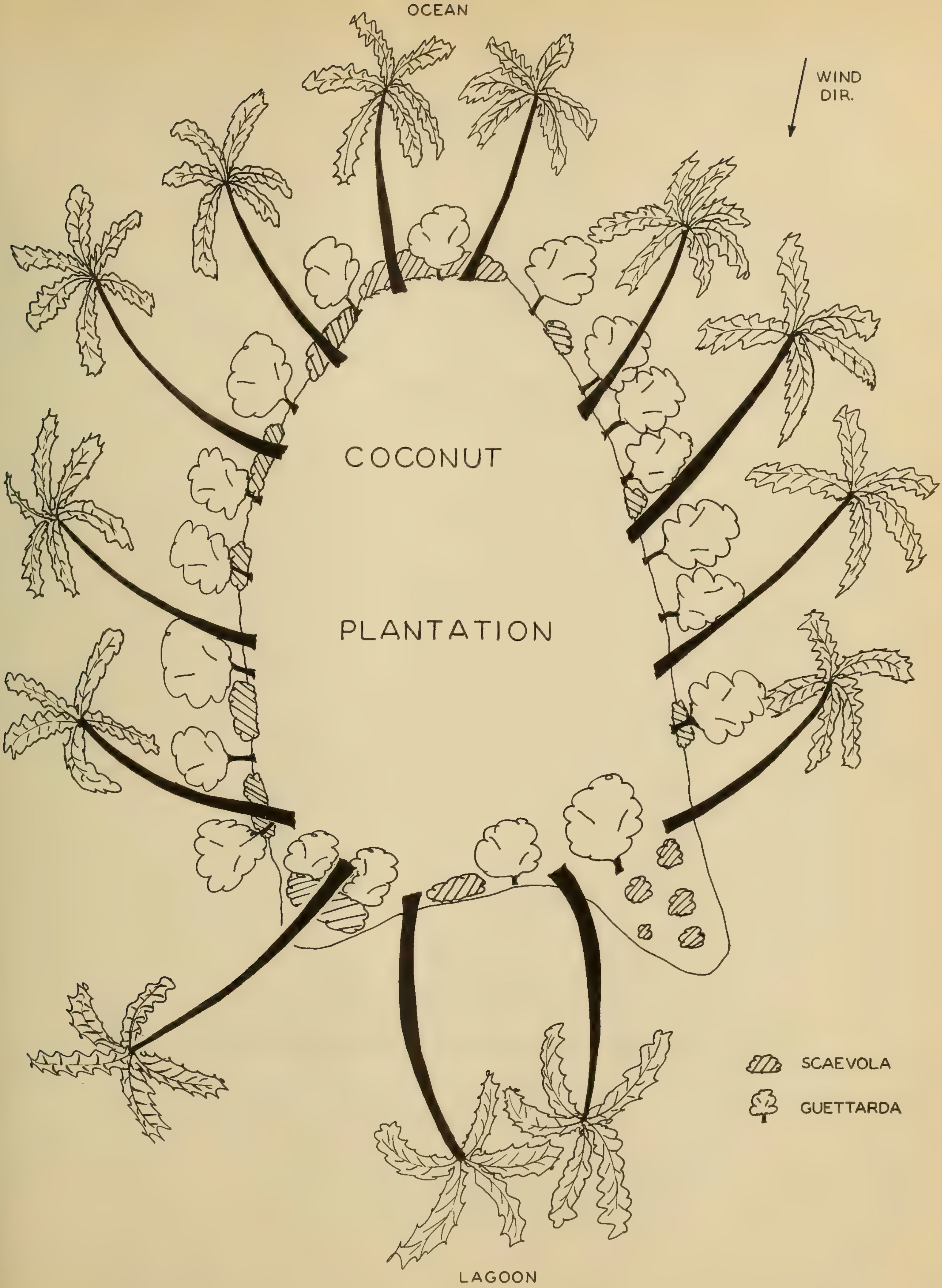

OCEAN
WIND DIR.
COCONUT
PLANTATION
SCAEVOLA
GUETTARDA
LAGOON

FIG. 33

ATOLL RESEARCH BULLETIN

No. 50

Geology of Kapingamarangi Atoll, Caroline Islands

by

Edwin D. McKee

Issued by

THE PACIFIC SCIENCE BOARD

National Academy of Sciences--National Research Council

Washington, D. C.

June 30, 1956

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INTRODUCTION

Kapingamarangi Atoll is located at the southernmost end of the Caroline group of islands, slightly more than 1° north of the Equator. It is about 410 miles southeast of Truk and 350 miles north of Rabaul in New Britain. This isolated atoll surrounds a lagoon about 6 miles across from east to west and slightly less from north to south. It is inhabited by 426 Polynesians (1954), most of whom live on Touhou and Werua Islands on the eastern side. Details of geographic setting, climate, and general environment have been treated H. J. Wiens so will not be included here.

This report on the geology of Kapingamarangi Atoll covers preliminary results from field investigations conducted during late June, July, and August of 1954 and laboratory examination of specimens made during the winter of 1954-1955. Much attention has been devoted to studies of the islands, with special emphasis on the classification of sediments and sedimentary rocks, the occurrence and behavior of ground water, and the distribution of soils. Detailed studies also were made of the processes of sedimentation that currently are operating both on the reef and in the lagoon. These studies included the making of detailed analyses of beach and bar structures, the reconstruction of reef and offshore profiles, and the systematic sampling of the lagoon floor.

Terminology used in this report follows, in general, that recommended by Tracey and others (1955) in their recent paper titled "Conspicuous features of organic reefs." The term "atoll" is used for the peripheral reef and everything within it. The upper surface of the peripheral reef, except where covered by islands, is referred to as the reef flat. Small reefs within the lagoon, including varieties that have been called patch reefs, small table reefs, reef knolls and reef pinnacles, are discussed under the general designation of patch reef. Dense growths of staghorn or branching corals are referred to as thickets. Other terms for geomorphic and organic features are explained in the text wherever their meaning is not apparent.

ACKNOWLEDGMENTS

The geological investigation described in this report was conducted as part of a project of the Pacific Science Board of the National Research Council and was supported by funds from the Office of Naval Research through its contract N7onr-29104 (NR 388 001) with the National Academy of Sciences. The U. S. Navy Department and the Military Air Transport Service furnished transportation to and from the atoll and the Navy Department assisted greatly by supplying many items of equipment. The Civil Administrative staff of the Trust Territory of the Pacific Islands was helpful in many ways.

Many thanks are due Harold Coolidge, Lenore Smith, and Ernestine Akers of the Pacific Science Board for the help that they rendered the party. Appreciation is also expressed to Kenneth P. Emory of the Bishop Museum in Honolulu for his briefings on the atoll and its inhabitants and for personal

introduction to its people. Preston Cloud and Joshua Tracey of the U. S. Geological Survey were both extremely helpful with suggestions for the work and with the loan of scientific equipment.

My associates in the field party were Cadet Hand, Robert R. Harry, W. Jan Newhouse, William Niering, and H. J. Wiens, all of whom contributed in various ways toward the development of this report. The base maps of the islands prepared by Wiens were especially important in carrying out a geological program and the assistance of Niering in soil studies and tide recording is gratefully acknowledged. Kapingans who served faithfully as assistants throughout the summer were Taitos, interpreter, and Aisea, Exsol, and Turibureti, boatmen and test-pit diggers.

In the study of collections and samples of materials, I have been assisted by a number of specialists, and it is with pleasure that I acknowledge the following cooperation:

Coral identification -- John W. Wells, Cornell University.
Foraminifera identification -- Ruth Todd, U. S. Geological Survey.
Analyses of water from wells and lagoon -- John Hem, U. S. Geological Survey.
X-ray diffraction identification of minerals -- A. J. Gude III, U. S. Geological Survey.
Analyses of elements in soils -- P. R. Barnett, U. S. Geological Survey.

For critical reading of the manuscript and many helpful suggestions, the writer is indebted to G. D. Robinson of the U. S. Geological Survey, John Chronic of the University of Colorado, and Halka P. Chronic.

THE ATOLL FRAMEWORK

The peripheral reef of Kapingamarangi Atoll (fig. 24) encircles an oval lagoon, almost completely separating its waters, especially at times of low tide, from those of the surrounding sea. The only major breaks are relatively narrow passes on the south side where channels nearly 20 feet deep permit strong currents to flow in and out continuously. This peripheral reef includes what has aptly been termed the "frame" of the reef complex or reef mass, and is a lattice constructed through the growth of organisms, especially corals and coralline algae. As stated by Cloud (1952a, p. 2128), these organisms "serve to hold it /the reef/ together, and the frame they build is a trap for clastic or chemically precipitated sediments."

The surface of the peripheral reef is widest -- nearly 4,000 feet across -- near the northernmost sector, although it is almost as wide in the extreme western part (fig. 24). On the southern arc, west of the main passes, the surface is no wider than 1,000 feet. The 33 islands distributed along the eastern half of the reef appear as very low mounds that rise slightly above the general flat top along its lagoonward margin. They alone

stand above the level of high-tide waters. Elsewhere along the atoll, especially on the southwestern, western, and northwestern sectors, the reef surface is divided into a seaward slope and a lagoonward slope by a low but definite crest. Both slopes are extremely gentle in most places. They are referred to in this paper as the outer reef flat and the inner reef flat.

The essentially flat top of nearly all the outer part and some of the inner part of the reef forms a pitted rock pavement. Over wide areas this surface contains no organisms now contributing appreciably to growth of the reef. To the contrary, it appears to be solely the result of the wearing down, by waves and currents, of coral masses that once stood higher than the present surface. Evidence from Okinawa obtained by MacNeil (1950) indicates that similar surfaces there are the result of recent wave or solution planation. Other similar reef flats reported from many islands of the Pacific suggest, as stated by various geologists, that this widespread feature is the effect of a recent lowering of sea level with resultant death of all corals back from the reef edge, followed by a beveling of higher parts of the reef structure.

The present surface of the reef flat appears to result from an essentially static position of the sea for a time sufficient to develop a general evenness of planation and a condition of near sterility over wide areas. Today, small living algae of the genus Boodlea cover extensive areas of the rock surface; mollusks and other marine animals congregate around and under limestone boulders and coral heads that are strewn over the rock surface -- debris washed across from the seaward side. Brittle stars, eels, and marine worms inhabit cracks and cavities that extend down into the rock mass. Living corals and coralline algae, however, are largely restricted to the seaward margins of the reef and, where islands are absent, to waters of the inner reef area bordering the lagoon edge.

Clastic sediments are relatively scarce over much of the present reef-flat surface, but are progressively more abundant toward the inner margins of the reef where they form a veneer that covers a framework of coral. The small amount of fragmental material on the outer side of the reef flat consists largely of coral and coralline algal debris, up to and including boulder size, strewn over the surface, and of clastic particles from mollusk shells and echinoid spines, concentrated in pockets and cracks. Foraminifera of the genus Calcarina that are reported as common on the reef flats of many Pacific atolls are absent here; few Foraminifera of any type occur on the seaward parts of the atoll. The tests of these animals accumulate in quantities sufficient to form deposits of lime sand only on the island lagoon beaches and on the inner parts of the atoll. As pointed out by Sollas (1904, p. 6, 27), however, such lime sands ultimately fill many of the interstices in the framework limestone mass, and they develop into extensive deposits on the inner side of the "retaining wall" of coral and algal structures.

Attempts were made at Kapingamarangi to determine the lithologic character and structural features of the framework limestone through studies of material exposed in cracks below the pavement and of large boulders washed

up from seaward exposures. The investigation was hampered by the extreme difficulty of digging into the reef rock and by a general lack of natural breaks exposing sections, but from a series of samples some generalizations can be made. In many specimens, the reef rock appears aphanitic, but in others the relict structures of corals are clearly preserved.

The framework limestone as a whole seems to be very cavernous, although small masses and hand specimens commonly have a relatively low apparent porosity. Cavernous structure, observed in near-surface excavations, probably extends to considerable depths. This is indicated by the behavior of the fresh-water lens on various islands, in which all parts of the lens rise simultaneously and with a similar tidal lag (described under "Ground water"). It also is suggested by evidence from the drill holes at Funafuti (Sollas, 1904, p. 6) and at Eniwetok Atoll (Ladd et al., 1953, p. 2259). On the other hand, some of what originally were cavities appear to have been filled with clastic sediment. This feature has been noted by Newell (1954, p. 18) in reference to reef blocks from the outer edge of the reef flat at Raroia.

The reef-building organisms that contribute chiefly to the framework limestone, as judged by the forms currently growing along the eastern seaward margin of the atoll, are very largely corals but include some masses of the coralline alga Porolithon onkodes. The corals are represented by many species (table 9); the most common belong to the genus Acropora, except along the inner margin, where microatolls of Porites lutea are dominant. Suggestion that much of the limestone beneath the present reef flat is composed of a comparable assemblage is found in the mineral content of selected samples examined by X-ray diffraction methods.1/ All specimens tested show

1/ Analyses by A. J. Gude III, U. S. Geological Survey.

90 percent or more aragonite, which percentage probably reflects the proportion of coral, though a small amount of aragonite may be due to interstitial deposits of clastic shells. Five to 10 percent of high-magnesium calcite2/

2/ High-magnesium calcite, as opposed to low-magnesium or normal calcite, is discussed by Chave (1954, p. 267). He points out that calcite of algal structures contains more than 10 percent magnesium carbonate, whereas that in mollusks and certain other organisms contains less than 2 percent.

in some specimens suggests the amount of algal contribution. A lack of normal calcite in all samples indicates that the common reef-dwelling Foraminifera of the genus Amphistegina were not included in the samples examined.

Unfortunately, no data are yet available on the lithology or structure of the Kapingamarangi reef at appreciable depths below the pavement of the reef flat. Judging from records of wells drilled on other atolls (Fairbridge, 1950, p. 384), however, one might expect to find zones of clastic materials representative of various depths and environments, alternating with zones of reef-forming corals and algae similar to those on the surface today. All such changes at depth appear to be related to times of advance and retreat of the actively growing framework corals and coralline algae and probably were controlled by relative changes of sea level and still-stands. Both the upward

and the lateral development of the limestone framework are a record of tectonic and climatic events.

GEOLOGY OF THE ISLANDS

Character of the islands.- Thirty-three islands are distributed along the arc that forms the eastern, windward peripheral reef of Kapingamarangi Atoll. The largest is Hare Island, which is more than a mile long and 600 feet wide, and the smallest is Matukerekere Island, which is about 130 feet long and supports but a single mature tree. Some of these islands are composite, having attained their present sizes by the combining of two or more small islands through processes of sedimentation. Other islands probably represent various stages of diminution through partial destruction or dissection resulting from cyclonic storms.

The origin of islands perched on oceanic atolls is a problem about which man has speculated for a long time. Some early views on this subject are recorded in the log of Captain Cook (Lloyd, 1949, p. 266) under the date of April 17, 1777:

"There are different opinions amongst ingenious theorists, concerning the formation of such low islands as Palmerston's. Some will have it, that, in remote times, these little separate heads or islets were joined, and formed one continued and more elevated tract of land, which the sea, in the revolution of ages, has washed away, leaving only the higher grounds; which, in time, also, will, according to this theory, share the same fate. Another conjecture is, that they have been thrown up by earthquakes, and are the effect of internal convulsions of the globe. A third opinion, and which appears to me as the most probable one, maintains that they are formed from shoals, or coral banks, and of consequence increasing."

In order systematically to accumulate data relative to the islands on Kapingamarangi Atoll, geologic maps were prepared during the summer of 1954 for all of the larger and some of the smaller ones (figs. 1 to 10). Island maps on a scale of one inch equals 100 feet, compiled and surveyed by H. J. Wiens, furnished bases to work on. The distribution of materials was plotted according to the classification discussed in the section of this report on "Petrology." Dips in sedimentary strata were recorded on the maps.

Analysis of the geological maps indicates that Kapingamarangi islands are formed of three principal classes of material: (1) sedimentary rocks formed through the cementation of clastic particles and organic remains, (2) unconsolidated sediments of beaches and bars, and (3) surficial deposits forming the ramparts, rampart wash, and soils (not mapped) that partly cover and mask the other two. On the basis of the distribution and structure of these three classes of material, much of the island history may be interpreted.

Sedimentary rocks.- Beds of sedimentary rock rise above the reef flats along the seaward margins of all the large islands and many of the small ones, and they crop out locally within many islands. Because in most places the

clastic particles of which they are formed are clearly discernible and because their stratification commonly is prominent after weathering these rocks, for the most part, are readily distinguishable from the reef rock on which they rest. Isolated pedestals and undercut blocks formed of similar clastic rock stand on the reef flat considerable distances seaward from some islands -- remnants of earlier island masses. Conspicuous illustrations are on the flats east of Werua Island. Likewise, relict platforms of stratified clastic rock, worn to a low level through planation but standing above the coral rock of the reef flat, extend 400 feet northeastward from Torongahai Island.

Evidence furnished by the distribution of erosional remnants of stratified rock suggests that the seaward shores of all Kapingamarangi islands have been retreating for a considerable time. Similar evidence on Raroia, indicating reef-flat extension at the expense of islands, has been noted by Newell (1954, p. 14). A second feature that tends to support this concept is the orientation of cross-stratification along shore-line exposures of island rock. On many islands, of which Werua is an excellent illustration (fig. 4), the strata in rocks that form the seaward coast dip exclusively lagoonward over long stretches in the same manner and degree as strata in the modern lagoon beaches. This fact suggests that strata in the two places were developed in a similar manner and, therefore, that the deposits forming these rocks accumulated at a time when the lagoon margin was in the present position of the seaward shore. Still further evidence of island retreat is presence of the mineral apatite in coastal stratified rock on Nunakita and Ringutoru Islands in wave-washed areas beyond the present limits of trees. This location indicates that phosphorite must have developed at some time in the past when these localities were the interiors of islands and when guano from birds was accumulating nearby.

The present distribution of stratified rock indicates not only a former, more seaward position of the islands but also a higher surface level. Stratified rocks on various islands, especially prominent on Rikumanu and Ringutoru, stand 4 to 5 feet above the present high-tide level. These rocks are formed of clastic particles and are cross-stratified; they appear to be leached and partly phosphatized. Rocks having a similar high-level position in many atolls of the Pacific have been recorded (David and Sweet, 1904, p. 67-68; Ladd et al., 1950, p. 413) and are generally considered to represent deposits residual from a time when, owing to eustatic changes, sea level was higher than at present.

Lagoon beaches and bars.- Large parts of most of the present islands, including virtually all of the lagoonward sides, are composed of unconsolidated clastic materials and foraminiferal sands. Such sediments are accumulating today on the bars or horns projecting into the lagoon from both ends of each island and along the incurving beaches between these bars (figs. 1 to 10). Test pits and wells on various islands indicate that similar unconsolidated materials extend downward in many places at least as far as low-water level, 3 or 4 feet below the surface. Sedimentary structures, especially stratification, further show that these sediments were deposited largely as beaches, dipping lagoonward, and as bars.

FIGURE I. – GEOLOGIC MAP OF TORONGHAI ISLAND

0 500 Feet

1954

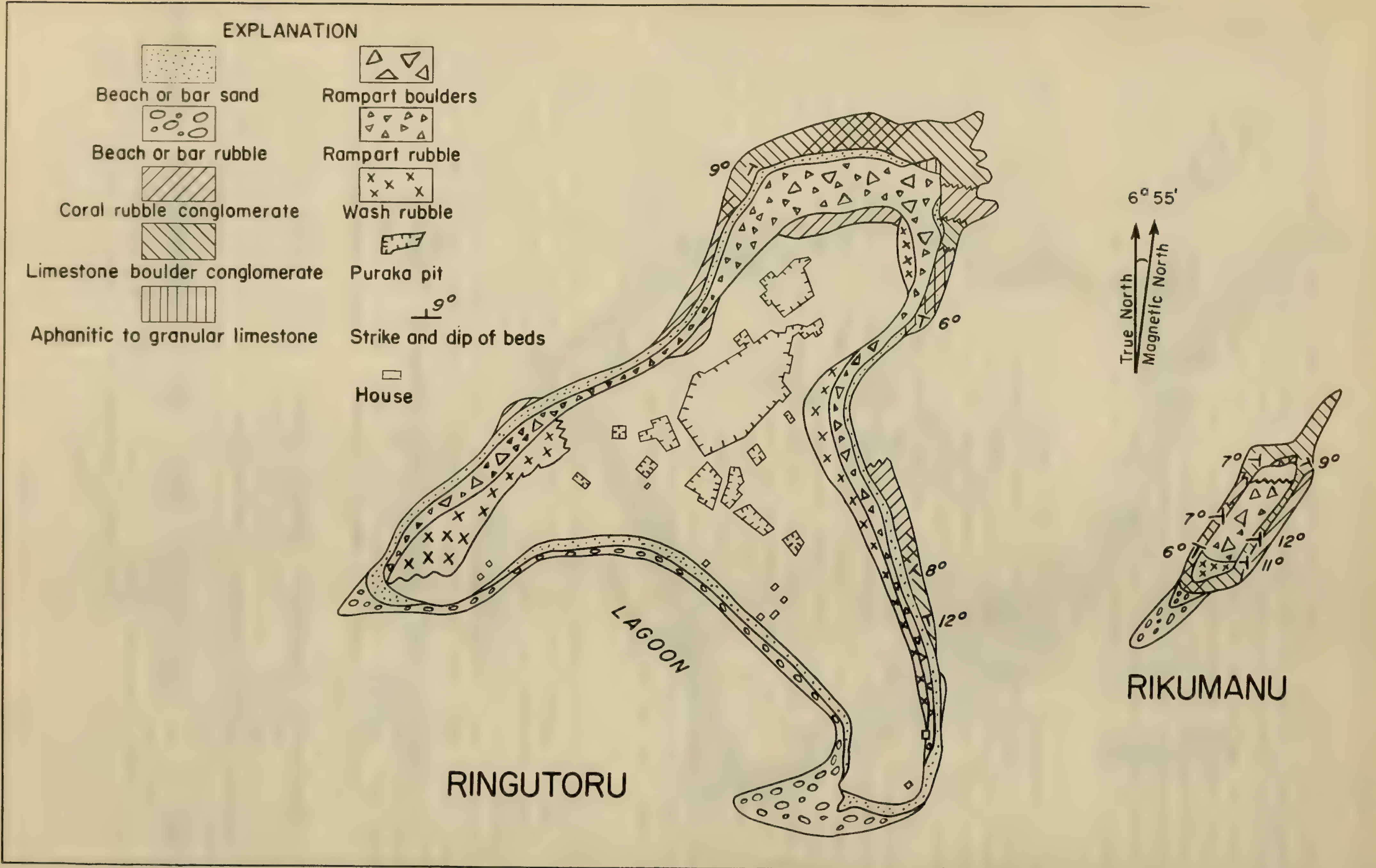


FIGURE 2.- GEOLOGIC MAP OF RINGUTORU AND RIKUMANU ISLANDS

0 500 Feet

FIGURE 3—GEOLOGIC MAP OF NUNAKITA ISLAND

0 500 Feet

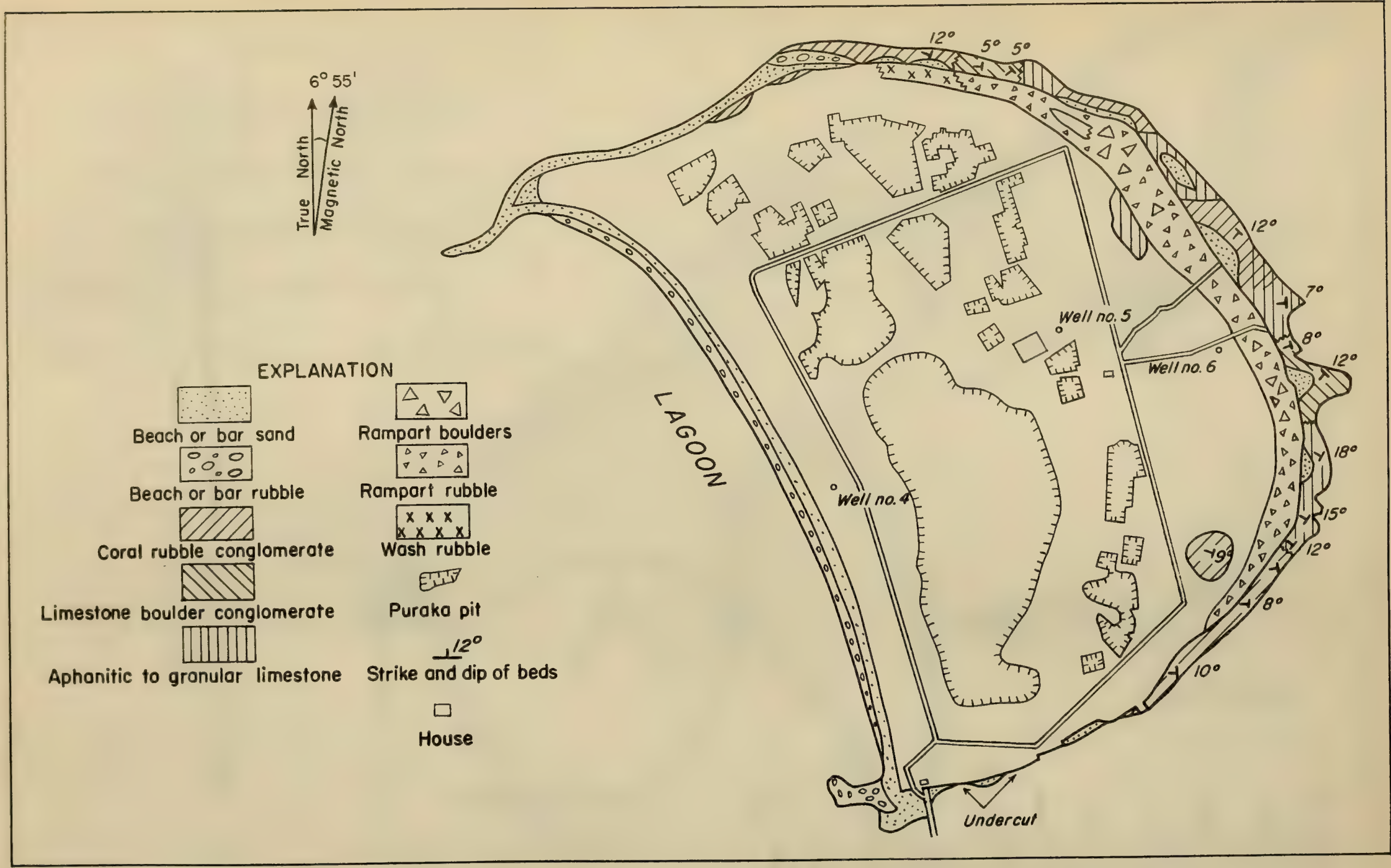


FIGURE 4.-GEOLOGIC MAP OF WERUA ISLAND

0 500 Feet

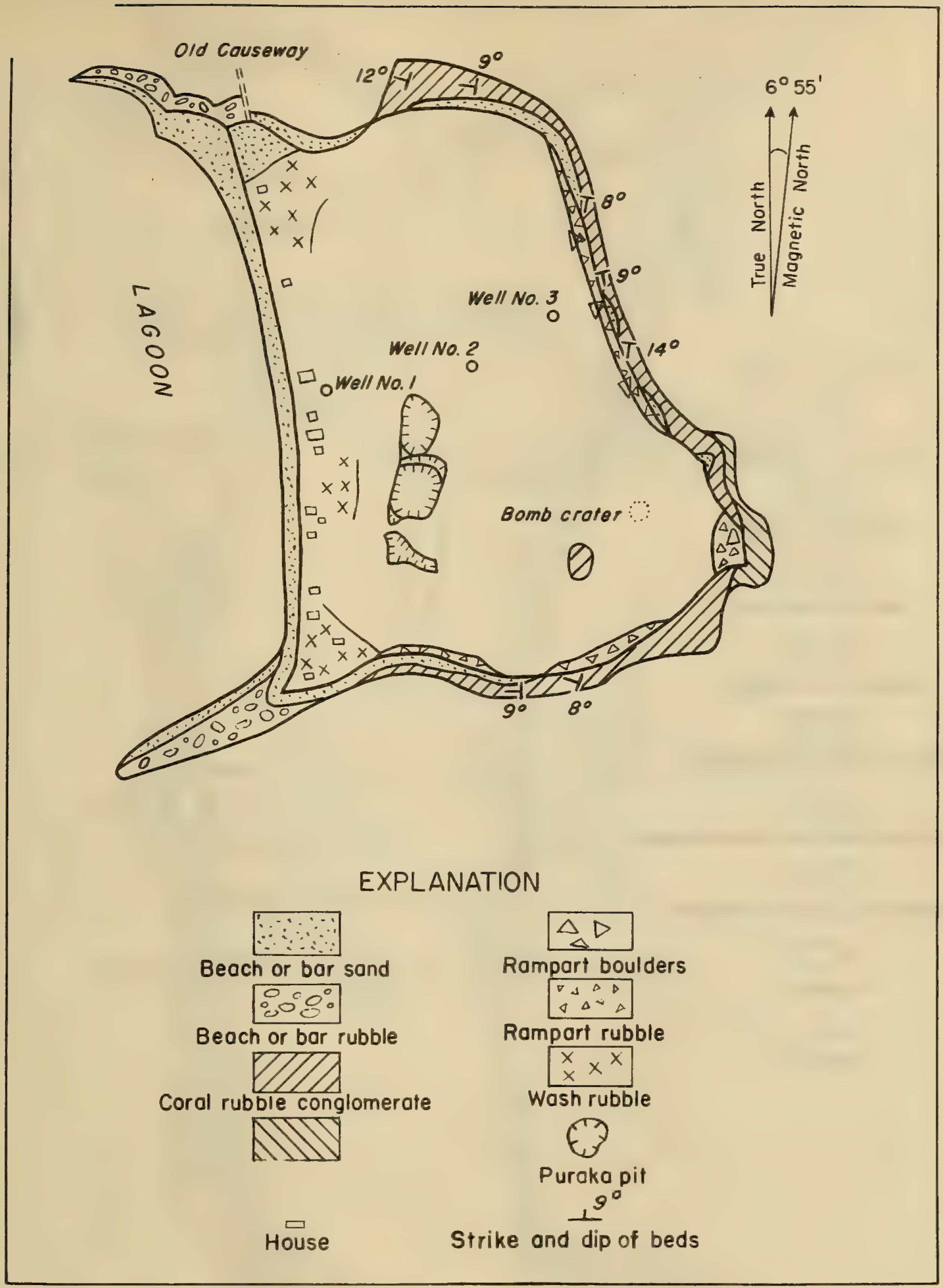


FIGURE 5.-GEOLOGIC MAP OF TARINGA ISLAND

0 500 Feet

1954

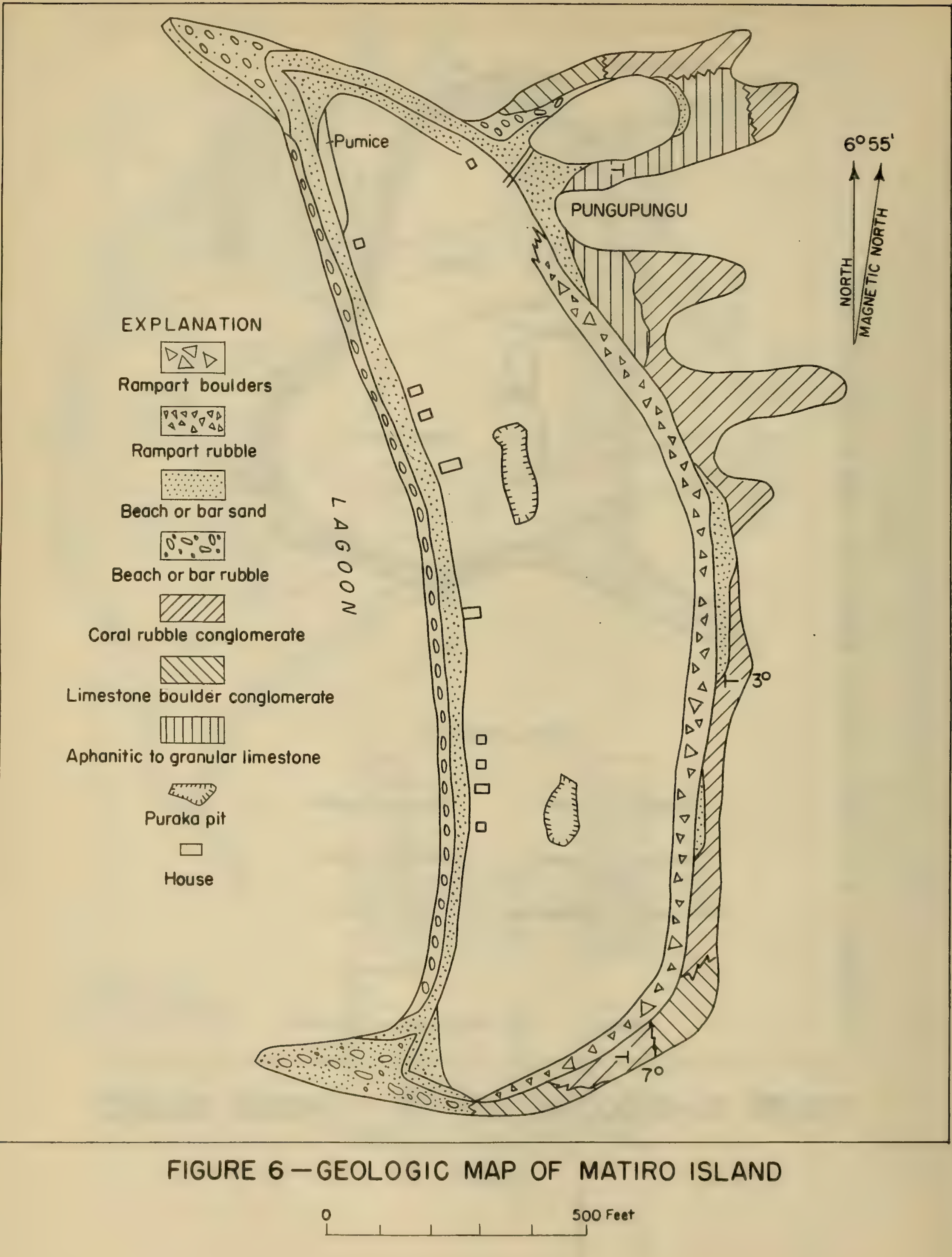


FIGURE 6—GEOLOGIC MAP OF MATIRO ISLAND

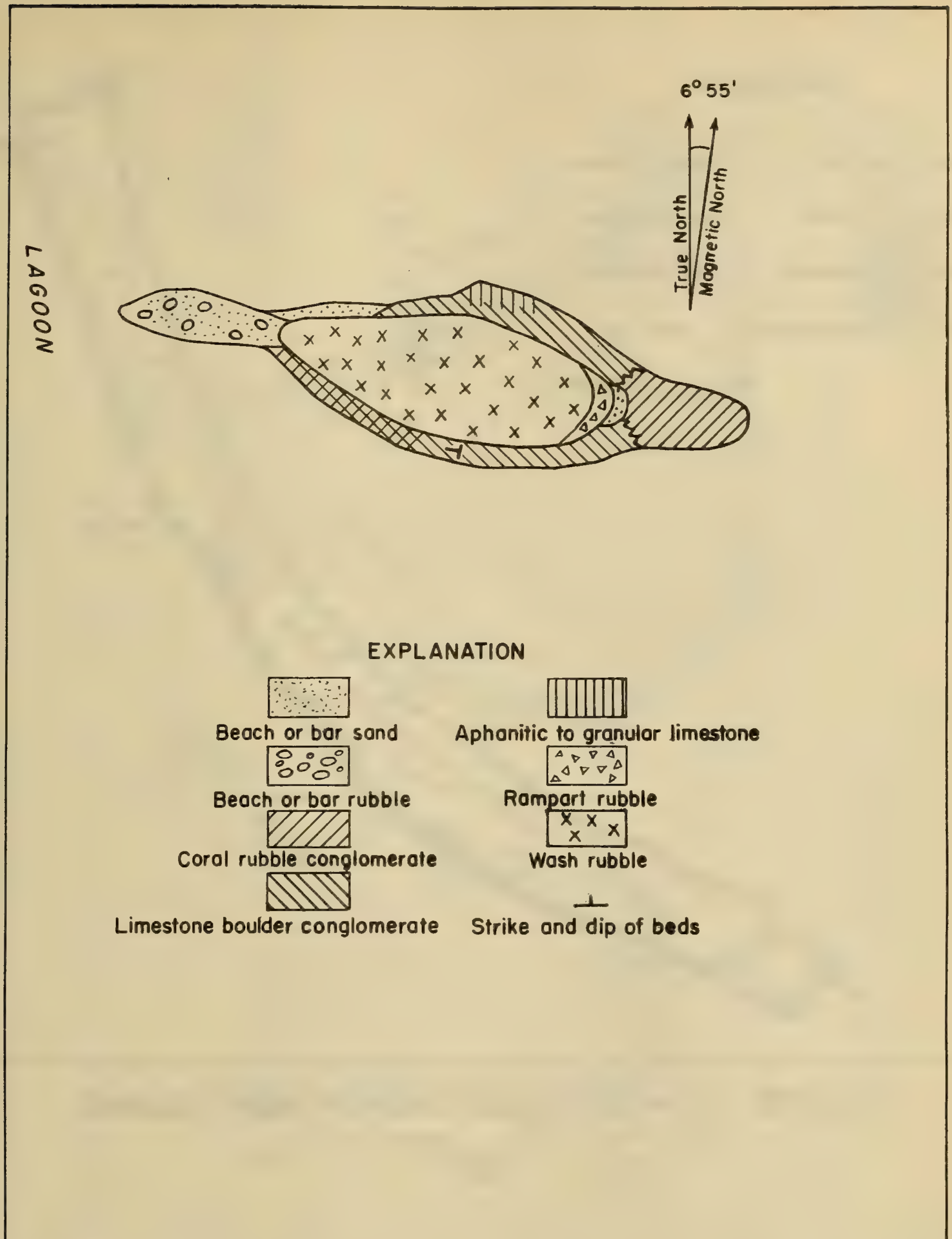


FIGURE 7.–GEOLOGIC MAP OF MATUKETUKE ISLAND

0 500 Feet

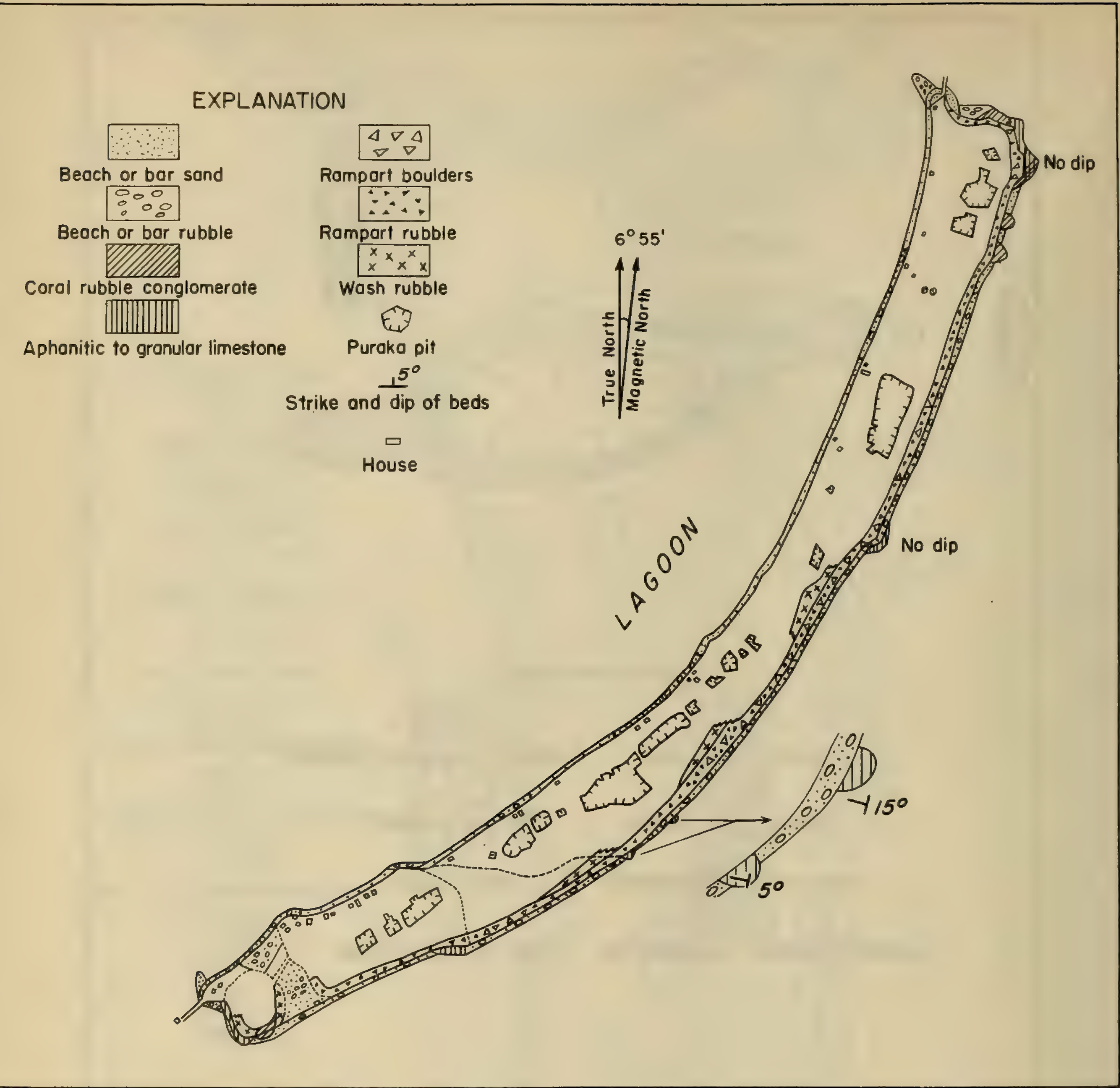


FIGURE 8.— GEOLOGIC MAP OF HARE ISLAND

0 500 Feet

1954

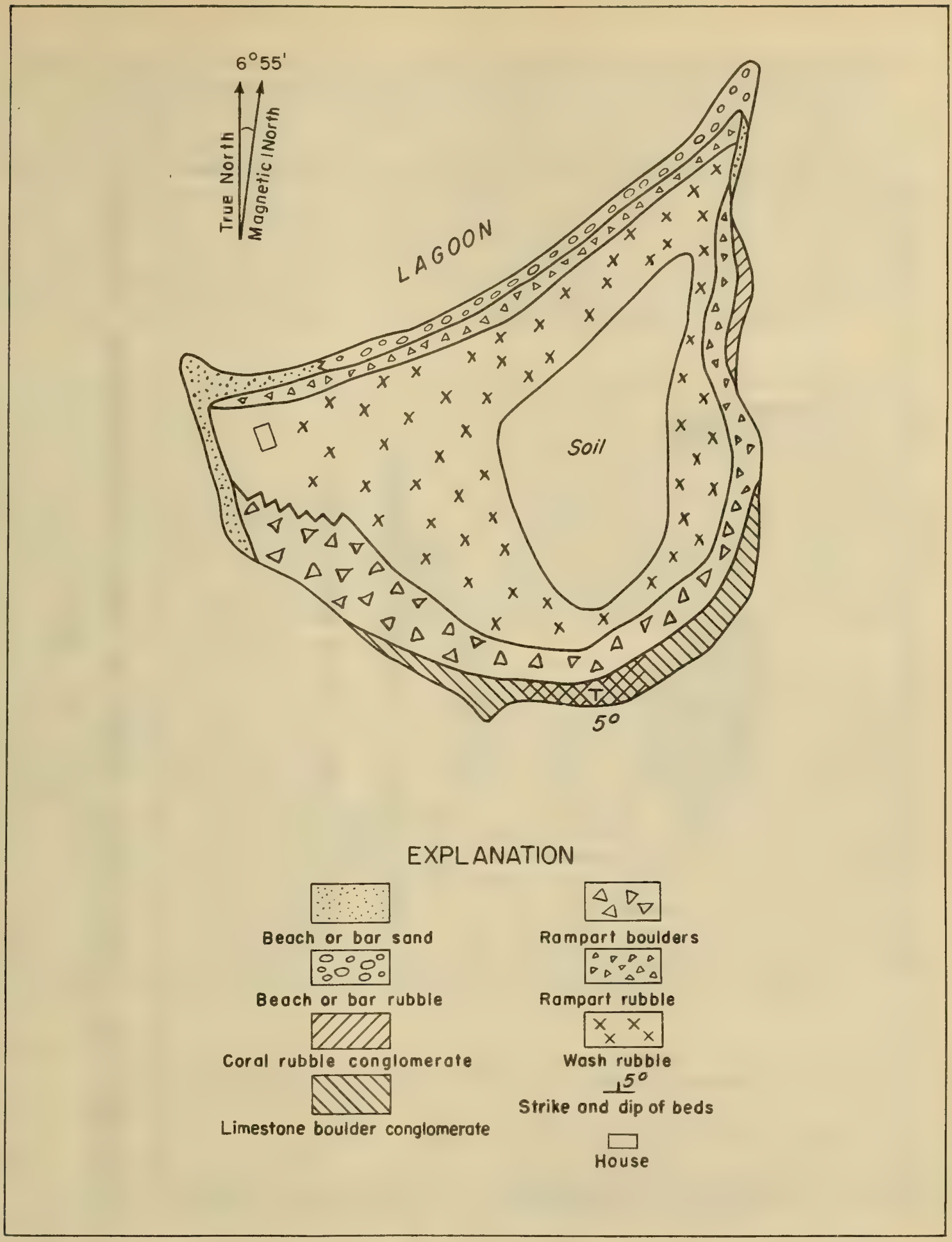
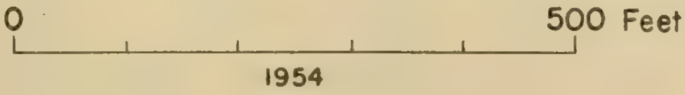


FIGURE 9.—GEOLOGIC MAP OF PUMATAHATI ISLAND



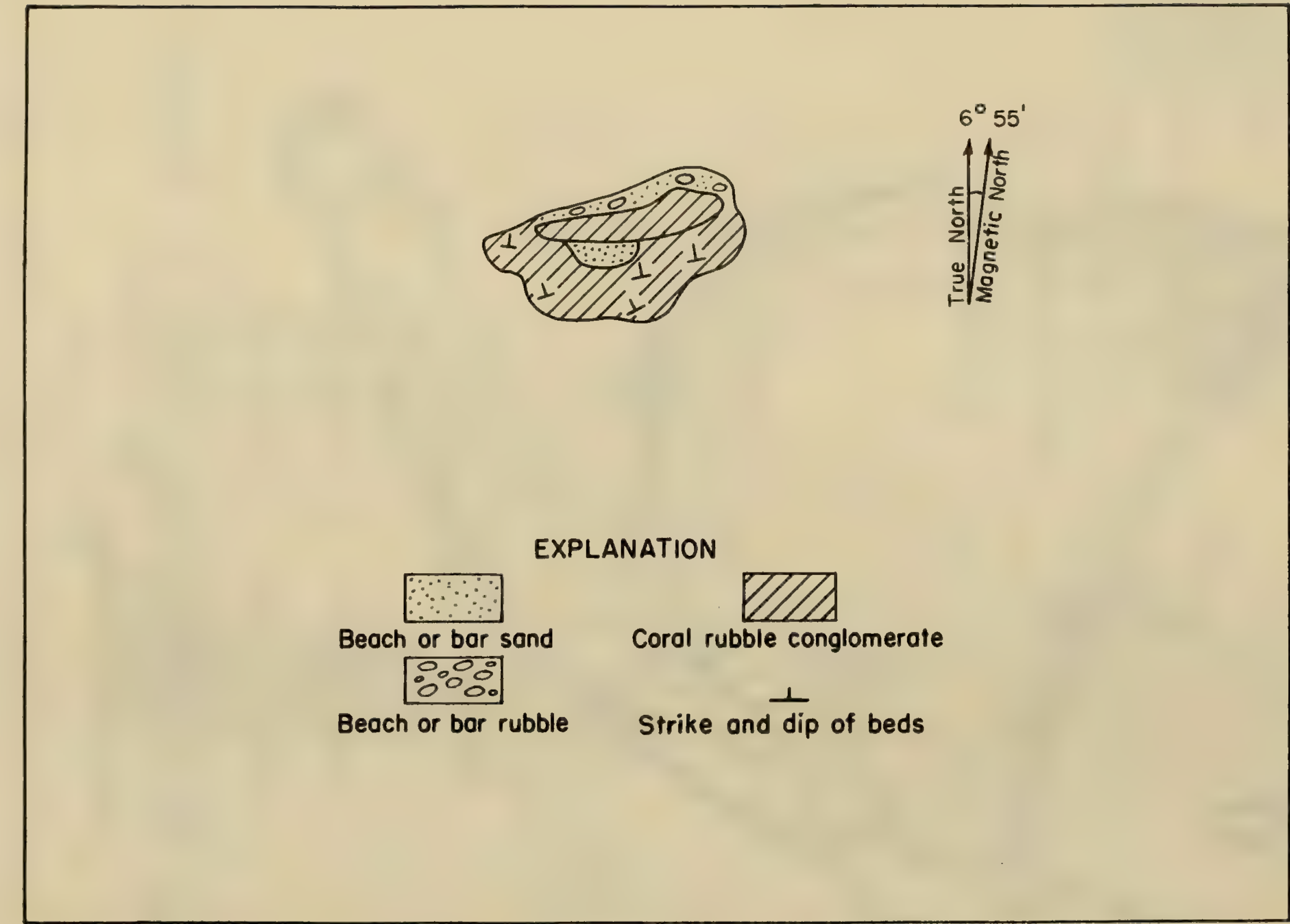


FIGURE 10.- GEOLOGIC MAP OF MATUKEREKERE ISLAND

0 50 100 Feet

Beaches and bars on all of the major islands were mapped, and details of their structure were recorded from trenches dug at right angles to the strand on Taringa, Parakahi, Matiro, Pumatahati, and Ringutoru Islands. Results of these studies must await description and analysis at a later date, but some salient features are shown on three typical beach profiles (fig. 11). The foreset beds of the beaches dip from 4° to 11° lagoonward, except for short distances immediately below beach crests, where many dip as much as 15° to 20° (table 1). Backshore beaches commonly are horizontal, but some dip inland 3° or 4°. No evidence that any of the lagoon beaches are being converted into beach rock could be found, and beach deposits encountered in test holes on the lagoon sides of many islands were unconsolidated.

Lagoon beach deposits vary in composition from time to time and from place to place according to effective wave conditions. Four principal components are recognized, and these are normally sufficiently well sorted that they are separated into parallel bands along the beaches. The components are (1) lime sand composed largely of an orange, ovoid-shaped foraminifer (Amphistegina madagascariensis), with lesser amounts of a white, disc-shaped foraminifer (Marginopora vertebralis); (2) white coquina sand composed largely of comminuted pieces of shell; (3) gray coral rubble, worn and washed, up to 1-1/2 or 2 inches long; (4) pieces of gray or black pumice averaging from 1/4 to 1/2 inch in diameter but some as much as 5 inches, worn and rounded except where broken along fresh fractures.

The sorting of beach materials according to weight and specific gravity results in pumice being concentrated on the backshore and the other three types of sediment on foreshore beaches. The orange foraminiferal sands today dominate the foreshore surfaces of most lagoon beaches, but on Pumatahati and parts of Hare Island, coral rubble covers the surface because of special conditions responsible for strong wave action. Test trenches show that at various times the beaches of all the islands have been covered by deposits of rubble, but most of these beaches were later buried by sand as they built forward under conditions of normal wave action. Island horns or bars that are now building out into the lagoon commonly consist in part of foraminiferal sand and in part of coral rubble, the distribution of each material depending on conditions of local current and wave strength.

Table 1.-- Characteristics of lagoon beaches

Island	Width, low tide (feet)	Angle of dip toward lagoon (degrees)		
		Foreshore slope	Subcrest slope	Backshore slope
Taringa	23	5 - 11		
Parakahi	23	5 - 10	15	
Matiro	15	7	16	
Pumatahati	20	4 - 9	(Rampart 29)	
Ringutoru	26	9	15	0 - 4
Torongahai		8	20	0 - 2

Unconsolidated deposits of beach and bar that form major parts of some islands on Kapingamarangi furnish evidence that sedimentation has caused the lagoonward sides of these islands to build forward at an appreciable but undetermined rate. Beach trenches show the recent accumulation of backshore deposits over earlier foreshore sediments; test pits near the shore expose humus layers mixing with backshore deposits; wells in the interior bring to view sequences of lagoonward-dipping foraminiferal sands of former beaches. Most conspicuous of all features furnishing evidence on beach migration is the presence of relict zones of pumice, located back from the margins of some beaches and marking the backshore accumulations of earlier periods.1/

1/ Similar bands of pumice on Addu Atoll have been reported by Sewell (1936, p. 77).

Whether this aggradational process is as rapid as or more rapid than the rate of island destruction on the seaward side is not known. Presumably the rate of wearing back of land has decreased in proportion to the distance from the reef front during the current still-stand of the sea. Although the present reef flat is relatively wide in most places, there is ample evidence that erosive forces of the sea are still very effective on many of the islands. On the other hand, the rate of island building through sedimentation may be retarded as the shore moves forward into continually greater depths of the lagoon, requiring greater amounts of sediment to build up the bottom.

Seaward beaches.- Beaches are relatively scarce on the seaward sides of Kapingamarangi islands; furthermore they are small and short-lived. Most of them are perched on the bevelled surfaces of stratified island rock at various distances above low-tide level. As indicated on the geologic maps (figs. 1 to 10), few of them are continuous for long distances along the shores. It is doubtful that any of these beaches make permanent contributions to the growth of the islands.

The seaward beaches differ from the beaches on the lagoon sides of islands not only in being more patchy and far less extensive, but also in composition and color. They are formed largely from comminuted shells of mollusks and are white, in contrast to the orange lagoon beaches, which are mostly composed of Foraminifera. A small beach at the seaward end of Pungupungu Island (fig. 6) forms a coquina composed almost entirely of unbroken shells of a small pelecypod of the genus Trigonocardia.

Ramparts and rampart wash.- Accumulations of clastic debris consisting largely of coral rubble, coral heads, and limestone blocks are deposited on the borders of most islands, above wave-cut benches and beach crests, by occasional violent storms. The deposits are classified as boulder ramparts and rubble ramparts, according to their constituents, or as rampart wash where the debris has been spread out as a sheet below and beyond the inland part of the rampart ridge.

Present distribution of these surficial deposits, shown on the geologic maps of the islands (figs. 1 to 10), gives some indication of the directions

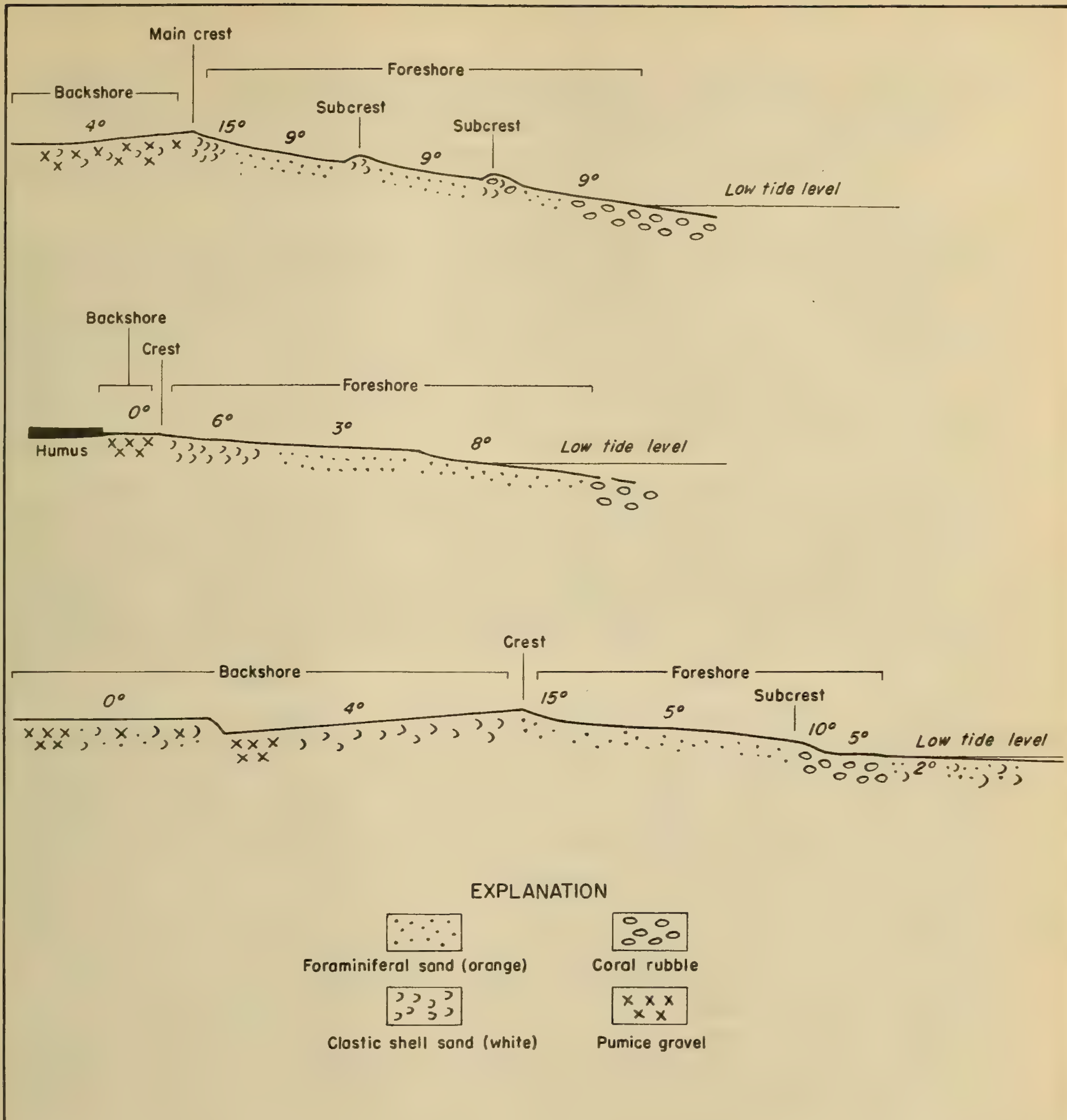


FIGURE 11.-PROFILES OF LAGOON BEACHES AND DISTRIBUTION OF BEACH SEDIMENT

0 5 ft.

of approach and the intensities of recent storms. Large islands along the northern arc of the atoll -- Torongahai, Ringutoru, and Nunakita -- all have large ramparts on both eastern and western shores. The widest are on the western sides and in these the largest blocks (36 inches in diameter on Torongahai) are concentrated near the northern ends (table 2).

Islands of the eastern arc -- Werua, Matiro, and Hare -- have ramparts on their eastern seaward sides, but these ramparts are formed mostly of fine rubble with very small areas of boulders. Individual blocks are on the average much smaller than on northern islands (table 2). On the southern arc, at Pumatahati Island, large ramparts have been formed on both seaward and lagoonward shores. The rampart to seaward consists largely of boulders; that on the lagoon side of coral rubble only. The unique development on this island of a lagoon-facing rampart must be attributed to a fetch sufficiently great to allow easterly storms in the lagoon to reach high intensity.

Rampart wash, as indicated on most of the maps (figs. 1 to 10), extends inland from the ramparts for distances as much as 250 feet, forming a surface covering of coral rubble. Because rampart wash has developed largely on the seaward sides of islands, it rests on bedrock in many places, on soil in others. Apparently it is the result of waters washing a part of the gravels and other small constituents of the rampart beyond its crest. On the northern islands especially, rampart wash covers extensive areas back from the seaward margins.

Migration of islands.- In preceding sections of this paper, geological evidence has been cited showing that the seaward sides of islands are currently being eroded back so that the outer reef flat is becoming wider at the expense of island stratified rock, and that the lagoon sides of islands are constantly growing through accumulation and deposition of beach and bar sediments. The total effect, therefore, is that of island migration across the reef, from seaward to lagoonward side. So long as sea level remains relatively stable with respect to the atoll, this process may be expected to continue, though increasing distance from the reef front causes the effective cutting power of waves to decrease, and the advance of the lagoon shore into progressively deeper waters requires more and more sedimentary material to build up a comparable amount of beach front. J. I. Tracey (written communication, July 1955) suggests that solution of rock is more effective than abrasion by waves in the retreat of islands and that wide reefs favor rapid solution. He also suggests that wide reefs may favor rapid sedimentation as they probably provide more sediment. Thus, it is not known whether or not these islands migrate at a progressively slower rate.

In addition to the evidence of island migration already given, many biological features support the thesis. One of the chief among these is the undermining of trees -- especially coconut palms -- by waves on the seaward shores. Many such trees are tilted or have fallen outward from the islands. The Kapingans are aware of the effectiveness of this process and on both Touhou and Werua Islands have constructed stone embankments along the southeast coasts to protect the land. Evidence of the recent growth of lagoon shores is found on several islands where successive lines of certain shore-fringing species of trees are now standing in the interiors, marking the sites of former shore lines. Detailed studies of the relations of

island migration to plant life were made by William Niering during the summer of 1954, and results have been reported by him.

On Kapingamarangi Atoll, island migration appears to have been, in general, greatest for the northern islands and least for the southern. This is indicated not only by a greater width of outer reef flat in the north than in the south, but also by the extent to which bevelled remnants of stratified bedrock extend outward from the seaward coasts of Torongahai, Ringutoru, Nunakita, and Werua Islands (figs. 1, 2, 3, and 4). In contrast, Hare Island, on the southern part of the atoll, appears to have been relatively stable; it shows little evidence of shore recession on the seaward side and does not appear to be building out rapidly lagoonward. 1/ Its adjacent outer reef flat

1/ Its lagoon beach probably is the type of that at Arno Atoll described by Wells (1951, p. 5) as "degrading." Much of its surface is covered by rubble concentrates, the sand having been removed, and several coconut palms growing near it are partly undermined.

is comparatively narrow.

Problem of Kapingamarangi beachrock.- Essentially all of the rock forming the islands of Kapingamarangi Atoll is composed of calcareous skeletal debris and rock fragments, cemented by calcium carbonate. It varies greatly in texture and in degree of cementation, some being extremely friable, some well cemented and dense. Much of it is stratified or cross-stratified, and it has all the characteristics normally attributed to beachrock. Details of its origin are not entirely clear, however, despite the numerous suggestions concerning the origin of beachrock that have been offered in the many publications on this subject.

Because modern beachrock is limited to tropical seas, its relation to warm waters appears to be beyond question. Because it develops exclusively in the intertidal zone, its relation to the rise and fall of tides seems equally definite. Other factors -- those responsible for its localization on certain beaches or parts of beaches -- are less clear. Basic requirements in the development of beachrock have recently been summarized by Ginsburg (1953, p. 88) as (1) high temperature, (2) rapid rate of beach drainage between high tides, and (3) a permanence of beach deposits sufficient to allow the cementation process to operate. The localization of beachrock is commonly explained as due to the precipitation of calcium carbonate from sea water as a result of heating and evaporation. The probable importance of blue-green algae as agents that bind sand grains together until they can be cemented has been suggested by Cloud (1952b, p. 28) and others.

As a result of observations on various Pacific atolls, a divergence of conclusions has been reached concerning the areas in which beachrock is currently developing. Ladd and others (1950, p. 416) state that on Bikini Atoll "beachrock may be formed between the reef flat and the beach." These authors refer to the fresh look of the rock and the original color of organic inclusions as evidence that lithification is going on today, but also point out that exposed parts of the beachrock are being eroded. Regarding Onotoa Atoll, Cloud (1952b, p. 28) describes "bonded limesand," which he considers to be incipient beachrock, forming on lagoon beaches, in tide pools, and in spray pools, and states that it was not found on this atoll anywhere on the seaward

Table 2.--Distribution of ramparts and rampart wash

	Island	Boulder rampart			Rubble rampart		Rampart wash	
		Location	Width (feet)	Size of boulders (inches)	Location	Width (feet)	Location	Width (feet)
Northern	Torongahai	West shore East shore	47-72 28-32	36 12	South part of east and west shores		Blanket bordering rampart	15-92
Northern	Ringutoru	North shore West shore East shore	115-164 18-77 21-54	24 6-10 6-12	Part of west shore		Southwest end borders east rampart	30-200 23-72
Northern	Rikumanu	Entire surface	100	18-24				
Northern	Nunakita	West shore East shore	22-100 31-68	12-36 6-8	South part of east and west shores		North end borders east rampart	250 32-96
Eastern	Werua	Southeast shore	57-120	24	South shore East shore	36-60 75-100	Borders east rampart	
Eastern	Matiro	Southeast shore, small area		6-24	East shore	16-40		
Eastern	Matuketuke	East end	32	6-24			Entire surface	150
Eastern	Hare	Northeast shore	42-67	6-12	East shore Southeast shore	31-100 36-45	Borders east rampart	33-85
Southern	Pumatahati	South shore	33-100	6-12	North shore	15-20	West end borders rampart	250 30-100

beach. Concerning Raroia Atoll, Newell (1954, p. 32) says that beachrock is quite rare along lagoon shores, but that it appears to be forming in "moats" in the island interiors -- behind lagoon shore ridges and, especially, back of seaward ramparts. This is probably the Cay Sandstone of British and Australian geologists.

Most of the beachrock exposed at Kapingamarangi Atoll today appears to be relatively old. This is suggested by (1) the presence of typical beds preserved as relict deposits standing above present high-tide level on several islands, (2) the bevelled remnants of typical beachrock extending seaward a few hundred feet, across the reef flat, from the present island shores, and (3) evidence of replacement of calcium carbonate by apatite in strata both in the interiors and on the shores of several islands.

Although considerable evidence indicates that active erosion dominates the seaward shores of most Kapingamarangi islands today, there is reason to believe that, locally at least, some lime precipitation is going on contemporaneously. On the reef flat near the shore of Parakahi Island a rectangle of boulders placed there by man at an unknown date has been firmly welded in place through cementation. On the east shore of Tirakaume Island, a 3-foot block of stratified limestone from an ancient outcrop of beachrock is now standing on end, incorporated in the present middle beachrock layer. How recently this development took place is not known, but it clearly shows a second stage in beachrock development. Such illustrations of recent, though local, precipitation of calcium carbonate on the seaward shores of islands are supported by records from other atolls. These include the record of a fragment of green glass from a Japanese fishnet float, embedded in beachrock deposits at Bikini (Ladd et al., 1950, p. 416) and the report of a firmly bonded gravelly sand containing brass cartridge shells on the seaward shore at Tarawa (Cloud, 1952b, p. 29).

On Kapingamarangi Atoll no development of beachrock on the lagoon shores of the islands could be detected. Although a large number of test trenches were dug across the beaches of various islands and most of the beaches were examined in connection with mapping of the islands, without exception they were found to be entirely of normal unconsolidated deposits of sand and gravel. Likewise, no clear evidence of beachrock development was found in the island interiors, for "moats" that are periodically flooded by sea water as described by Newell (1954) for Raroia do not occur at Kapingamarangi. Thus, if beachrock is forming today in appreciable amounts on the islands of Kapingamarangi, it must be on the seaward sides. Most of the rocks on these sides, however, appear to be wearing away rapidly, so it is doubtful that beachrock development is extensive there at present.

The theory that beachrock may develop by the work of ground water that dissolves calcium carbonate from lime sand and precipitates it as it seeps through the beach at low tide was proposed many years ago (Field, 1920, p. 215). Considerable evidence opposed to this idea has since been presented by Daly (1924, p. 138) and others. On the islands at Kapingamarangi, it clearly cannot apply because (1) intertidal sediments on the lagoonward margins of islands are not lithified, (2) bedrock on the seaward side rises above high-tide level and extends inland a considerable distance, and (3) no correlation between the water levels and island bedrock can be detected in the series of wells across Taringa and Werua Islands (figs. 14 and 15).

Sedimentary material that forms the atoll of Kapingamarangi is, with few exceptions, composed of calcium carbonate. Part of it is unconsolidated accumulations of clastic particles. The remainder, referred to as sedimentary rock, is lithified material developed through cementation of these clastic sediments and from the reef-building processes of corals, algae, and other organisms. For purposes of studying and mapping, principal varieties of sediment and sedimentary rock have been classified into easily recognizable types, based primarily on texture and secondarily on the major contributing organisms or rock ingredients.

Sediments.- Unconsolidated materials are separated into three groups according to particle size, following the Wentworth classification of detrital sediments. These groups are (1) lime gravel, in which particles are greater than 2 mm in diameter, (2) lime sand, in which they are between 1/16 and 2 mm, and (3) lime mud, in which they are less than 1/16 mm. Deposits of all three of these groups form significant parts of the atoll, and each accumulates in characteristic situations, as will be described later. Both lime gravel and lime sand are concentrated on the reef flats, locally forming deposits from which the islands are built. They also cover much of the lagoon floor. Lime muds, on the other hand, are confined largely to the deepest parts of the lagoon.

Two principal varieties of lime gravel are recognized. One is referred to as boulder gravel, for it contains angular blocks of reef rock, rounded coral heads, or masses of coralline algae which are of boulder (>10-inch) size. The other is formed almost exclusively of coral rubble, derived largely from broken fragments of Acropora or elk-horn coral ranging from about 1/2 to 2-1/2 inches in length. Although many mixtures or intermediate stages between these varieties of gravel exist, the importance of recognizing them as separate types is that the boulder gravel indicates the action of violent storms and accompanying large waves, whereas the much smaller coral rubble is transported also by normal waves and currents, and so is being deposited almost continuously.

Lime sands of Kapingamarangi Atoll vary according to the organisms or combinations of organisms from which they have been derived. Those of the beaches and shallow offshore waters are composed largely of the small orange foraminifer Amphistegina madagascariensis, the white wheel-shaped foraminifer Marginopora vertebralis, or both. Some beaches contain a high percentage of white fragments of mollusk shells; elsewhere beach sands locally consist of tiny, unbroken pelecypod shells forming coquinas. Some shallow-water lime sands, especially on the tops of patch reefs, include large amounts of tiny coral fragments; and in waters more than 80 feet deep, sands are formed almost exclusively of fragments of Halimeda (calcareous green algae) or of the hemispherical pale-olive foraminifer Amphistegina lessonii.

Pumice is abundant on the backshore beaches of most islands. Much of it is of granule or small-pebble size, but a few fragments are as much as 6 inches in diameter. Most of the pumice is light gray; some is black. Large specimens commonly are well rounded. This material is so concentrated on some backshores as to form essentially pure pumice layers.

Lime muds include (1) some small deposits of silt (1/16-1/256 mm) derived from shells or other organic structures and (2) extensive deposits of very fine pale-olive oozes which are sticky when wet. The silts develop largely at moderate depths in lagoon channels or other places where there are currents strong enough to gather and transport them. The calcareous oozes form only in the deepest parts of the lagoon bottom. They are composed mostly of clay-sized particles of calcium carbonate but include perhaps 10 percent of Foraminifera, largely of very small species not found in the shallower waters (discussed under "Sedimentation in the lagoon"). This calcareous ooze has high plasticity and contains a slimy residue of organic matter conspicuous for its fetid odor when wet.

The mineral composition of Kapingamarangi sediments as determined 1/ with X-ray diffractometer patterns shows wide variation depending upon the type of organism that dominates any particular sample (table 3). It is significant that the two common species of shallow-water Foraminifera are composed of essentially pure calcite, and the common foraminifer below depths of 100 feet, Amphistegina lessonii, is of nearly pure calcite. In contrast, corals including Acropora and other common genera are virtually pure aragonite except for a little calcite in their "dead" interior portions. Coralline algae of the genus Porolithon, which grow in abundance on the algal ridge of the outer reef, appear to be formed of calcite having a space-lattice different from that of normal calcite and interpreted by Gude as resulting from high magnesium content. Green algae of the genus Halimeda, which form important contributions to lagoon sediment below 80 feet, contain about 98 percent aragonite together with small amounts of calcite. The bottom calcareous oozes are about three-fourths aragonite and one-fourth calcite.

1/ Analyses by A. J. Gude III, U. S. Geological Survey.

Sedimentary rocks.- Carbonate rocks of various types form the outer reef, parts of the islands on the outer reef, and patch reefs within the lagoon. Four mappable varieties of these rocks are recognized, based on texture and structure. These are (1) coral and coralline algal limestone, (2) aphanitic to stratified clastic limestone, (3) coral rubble limestone, and (4) boulder conglomeratic limestone. The first and second types cannot everywhere be distinguished because of recrystallization and other modifications resulting from secondary processes; the third and fourth, in many places, grade from one into the other. Nevertheless, an attempt to recognize and map these types must be made if the processes developing the atoll are to be understood.

Limestone from corals and coralline algae forms the framework of the outer reef and of the patch reefs and can be seen developing today wherever contributing organisms are growing, especially along the outer margins of the reefs. The rock developed from these organisms forms the pavement on the present bevelled reef surface. It is difficult to examine in section, however, because of its extreme resistance to breakage and because of the

scarcity of exposed natural cuts into it. Samples from immediately below the pavement surface commonly show relict structures of organisms, as might be expected, but many appear aphanitic as a result of secondary processes acting on the calcium carbonate. Although hand specimens commonly appear to be low in porosity, the rock mass is cavernous and contains many cracks, some of which are filled with clastic debris.

Aphanitic to stratified clastic limestone forms an appreciable part of the bedrock on all islands and occurs in many places on the reef flats as pedestals and raised ridges considered to be relicts of former islands. Where the rock is aphanitic, little can be determined concerning its origin. Where planes of stratification remain or are etched out on weathered surfaces and characteristics of grain are preserved, however, the history of the rock can readily be determined. Dips of cross-strata and other characteristics show close similarity to features of the unconsolidated deposits of island beaches.

Boulder conglomeratic limestone and coral rubble limestone are major constituents of most islands on Kapingamarangi Atoll and form conspicuous ledges and shelves along many of the seaward shores. The limestones are easy to recognize because the gravel within the lime matrix normally weathers into prominence and, in some places, is extremely conspicuous because of color contrasts. Boulder limestone includes angular blocks of reef limestone, rounded coral heads, and masses of coralline algae of many sizes and shapes similar to those in modern boulder ramparts. The coral rubble limestone is formed entirely of small rubble in a lime matrix. These clastic limestones are distinguished in mapping, as are their nonlithified equivalents, because of the different origins that they imply.

The varied mineralogy of different limestones on the atoll doubtless is in part due to secondary processes of recrystallization and replacement. Many of the differences, however, are directly attributable to differences in the source materials. Foraminifera of which some rocks are composed are calcitic, corals in other rocks are aragonitic, and algal deposits in still others are high in magnesium (table 3). Therefore, fundamental genetic differences may account for the different compositions of many of these youthful limestones.

On a few islands phosphorite rather than limestone locally forms stratified rock. Phosphorite, presumably developed from the guano of sea birds through replacement of calcium carbonate, occurs on parts of Pumatahati, Nunakita, and possibly a few other islands. It is an earthy, light-colored rock resembling the local limestone in texture and structure, but commonly lighter in weight owing to high porosity. Mineral studies by Gude with X-ray diffraction patterns show that in some specimens the entire rock is composed of a variety of apatite.

Table 3.- Mineral composition of Kapingamarangi sediments as determined by X-ray diffraction patterns

Locality	Horizon (feet)	Description	Aragonite	Calcite A	Calcite B*
Lagoon, W. of Matiro	228	Calcareous ooze	80		20
Lagoon, W. of Romia	150	Calcareous ooze	60		40
Lagoon, W. of Sokoro	216	Calcareous ooze	70		30
Lagoon, W. of Tetau	224	Calcareous ooze	80		20
Lagoon, Tokahui	186	Sand (_A. lessonii_)		100	
Lagoon, Tokolala	90	Sand (_Halimeda_)	98		2
Lagoon, Matamatong	5	Coral branch	99		1
Lagoon, Matamatong	5	Core of coral	95	5	
Reef flat, Touhou		Algal crust (_Porolithon_)			100
Reef flat, Touhou		Algal crust (_Janea_)			100
Beach, Pungupungu		Sand (shell fragments)	95	5	
Beach, south reef		Sand (_A. madagascariensis_)		100	
Beach, south reef		Sand (_Marginopora_)			100
Beach, Matukerekere		Clastic coral, weathered	10		90

*Calcite A is interpreted as normal calcite; calcite B as magnesian calcite.

General statement.- Soils of Kapingamarangi Atoll are necessarily young: the islands on which they occur are of recent origin. Most of the soil profiles are classed as A-C profiles and consist of materials little altered from the parent rock or sediment, covered by or mixed with varying amounts of dark humus. The soils show few features of well-developed horizons such as normally result from long periods of decomposition of varied source materials.

Kapingamarangi soils characteristically are well drained and alkaline. They are largely mechanical mixtures of organic material and gravel, sand, or fine calcium carbonate particles. They vary from dark brown to gray and creamy white, according to the proportions of various constituents. Soil profiles all have dark layers at the top and light-colored bedded rock or sediment below, but some layers are separated by transition zones of intermediate color and composition, whereas others are marked by abrupt change.

In order to obtain quantitative data on the soils of Kapingamarangi Atoll, soil profiles were measured and samples for analysis were collected from eight wells, dug in connection with ground-water studies, and from eight test pits. These profiles were distributed on seven islands as follows: Werua 3, Taringa 3, Parakahi 1, Pumatahati 3, Ringutoru 3, Tokongo 1, Rikumanu 1. Conclusions resulting from studies of the soil profiles and of the analyses of samples constitute the basis for most of the following discussion on soils.

Parent materials of soils.- The simplicity of soils on the islands of Kapingamarangi stems, for the most part, from the fact that they are formed almost entirely from only two basic ingredients -- (1) parent rock or sediment composed of calcium (and some magnesium) carbonate, and (2) humus from vegetable matter. The carbonate material varies considerably in physical form. Much of it is limestone which makes up all the bedrock; the rest of it occurs as unconsolidated sediment including gravel, lime sand, and lime mud. Large clastic fragments include blocks broken from the reef, coral heads, and masses of coralline algae. Small gravel is almost entirely coral rubble. Lime sand consists of shell fragments and tests of Foraminifera, with local contributions of the alga *Halimeda* and other organisms. The lime mud appears to be principally from the decomposition of stratified rock or of limestone blocks. All these clastic materials mixed with humus are relatively little decomposed even though they are in an area of prevailing warm, humid climate. This indicates that the soil is very youthful.

Variations in the soils of Kapingamarangi are in part due to differences in the amount of original contamination and in downward filtration of vegetable carbon into the calcareous host materials. High permeability of much of the sediment, allowing rain water to enter readily, the penetration of roots as found in most test pits, and the work of various animals all contribute in varying degrees to downward mixing. In some places a "transition" zone (A_3 horizon) in which small percentages of carbonaceous matter

are mixed with coral rubble or lime sand has developed below the normal zone of incorporated organic matter (A_1 horizon) to a distance of 12 to 15 inches. In other places no "transition" zone is present.

Appreciable variations in the chemical character of the island soils (table 4) were not detected in the present study. In general, the youthfulness of the parent limestone virtually precludes the possibility that any appreciable concentrations of noncarbonate minerals have developed through leaching or decomposition. On the other hand, local additions to the soil may consist of pumice, bird guano, shells of crustaceans and echinoids, or skeletons of fish; the overflows of sea water possibly have affected the soil in some places. Backshore beaches composed largely or entirely of pumice (table 5) are present on the lagoon sides of several islands, and some pumice has been found in test pits, but its influence on vegetation in general is not known. Bird guano has contributed to the local development of phosphatic soil on some islands, especially Pumatahati, where according to native reports many frigate birds formerly roosted. Salts from sea water and sea spray that locally make soils highly saline have not left any conspicuous record of salt crusts, probably because evaporation is low as compared with contributions of fresh water; the salts do not seem to have affected large areas.

Alteration processes.- Factors conspicuous in bringing about the alteration both of soils and of the parent materials of soils on Kapingamarangi Atoll include those that remove substances, those that add substances, and those that mix substances. In the first category, one of the most important factors appears to be rain. Showers on the islands normally are short but violent, and permeable surfaces allow most of the water to enter readily with a flushing effect that probably accounts for the general lack of saline residues. Also significant is the abundant evidence of solution work in limestone beds, probably largely the result of carbonic acid from plants, which enables the migrating waters to dissolve carbonates.

At the low levels in the centers of some islands, especially where pits for growing puraka [1] have been excavated by the natives, ground water reaches the soil level and, locally, appears at the surface of the ground. Where this occurs, normal oxidation of organic matter is retarded or stopped by the water and black mucks develop. The fresh-water lens, moving up and down in response to tidal fluctuations, apparently has a considerable solvent effect on calcium carbonate in the soil wherever it comes within range, as shown by the calcium bicarbonate content of water samples from the wells.

Extraneous but significant elements in the soil include nitrogen, added by legumes and some types of algae. Calcium carbonate introduced through evaporation does not seem to be important, for no caliches such as occur in arid or semiarid regions were observed, and fresh water above the water table appears to be removing rather than contributing calcium carbonate.

A process that is especially important in the forming of soils through the mixing of materials is the burrowing of certain animals. Especially

1/ A plant with a tuberous, starchy root, related to the taro.

conspicuous are holes resulting from the activities of land crabs. Systematic studies of the distribution and effects of these animals on several islands were made by William Niering of the 1954 Pacific Science Board party. Probably also important though less apparent are the borings of earth worms; observations on the distribution of these were also made by Niering. The effects of roots in penetrating and breaking up soil materials were seen in the sides of all wells and test pits. Roots are effective only in the upper 1 or 2 feet of soil and sand, however, for their abundance and size diminish rapidly with depth. Only a few were observed as deep as 4 feet.

Relation of soil to position on island.- Because seaward and lagoonward parts of most islands on Kapingamarangi Atoll differ considerably in age, the stage of soil development on each side likewise is varied. On large and medium-sized islands the seaward sides are composed largely of limestone bedrock, believed to be relict from deposits of a former and higher stage of sea level, overlain in most places by rubble. In contrast, the lagoon sides of these islands are formed of relatively recent beach and bar deposits such as are developing today along the lagoon shores.

Excavations representative of the seaward and lagoonward sides and the centers of islands demonstrate the differences in their soil profiles. Wells and pits located approximately 100 feet from the lagoon beaches of Ringutoru, Taringa and Werua Islands show soil layers of $2\frac{1}{2}$-, 2- and 5-inch thickness, respectively (figs. 12, 14 and 15). Soil layers measured near the centers of the same islands are 8, 11 and 15 inches thick, and on the seaward sides 8, 14 and 32 inches. Small islands like Rikumanu and Tokongo, composed largely of bedrock from an earlier stage of sea level, probably correspond in age to the seaward portions of the larger islands. Commensurate with this age, soil layers of 29 inches on Rikumanu, and 18 and 7 inches on Tokongo were noted in test pits (fig. 13).

Buried profiles occur on the seaward sides of at least three islands and may be expected on others in corresponding positions. On Ringutoru, Taringa, and Werua (Figs. 12, 14 and 15) the soil profiles include a relatively thin upper layer of dark-brown soil, separated from a lower, much thicker soil by 9 to 24 inches of light-gray sediment, including sand, coral rubble, and small amounts of humus. This light-colored layer is interpreted as representing an interruption in the soil development process, during which time waters deposited clastic sediments. It is postulated that this deposition was a result of sheet wash at a time of storm activity. Much sand and some rubble, but no very coarse materials, are included. Judging from the appreciable thickness of the overlying layer of soil (4-9 inches), which is comparable to that of the entire soil layer on the other side of the island, and from the fact that buried profiles have not been found on the lagoon sides of any islands, a period longer than that required for development of the present lagoon side is considered probable for this interruption in soil formation. Thus, although the buried profile may be the result of some recent storm, more likely it dates back to the time of an earlier sea-stand.

Extremely youthful soil occurs locally where two islands have, within historic times, become joined through sedimentation resulting from causeway

Table 4.- Elements in Kapingamarangi soils determined by semiquantitative spectrographic method. Analyses by Paul Barnett, U. S. Geological Survey. Elements reported by percent ranges.

Well	Depth (inches)	Si	Al	Fe	Ti	Mn	P	Ca	Mg	Na	B	Ba	Cr	Cu	Pb	Sr
Werua #5	4	.01 .02	.02 .05	.1 .2	Not found	.002 .005	2 5	>10	.1 .2	.2 .5	.001 .002	.01 .02	.0005 .001	.001 .002	.0002 .0005	.5 1.0
Werua #5	20	.002 .005	.002 .005	.005 .010	Not found	.0002 .0005	.5 1.0	>10	.5 1.0	.2 .5	.001 .002	.0005 .001	.0002 .0005	.0001 .0002	Not found	.5 1.0
Werua #5	31	.01 .02	.01 .02	.02 .05	Not found	.0002 .0005	Not found	>10	.5 1.0	.2 .5	.001 .002	.002 .005	.0002 .0005	.0002 .0005	.0002 .0005	.5 1.0
Taringa #2	5	<.01	.02 .05	.05	<.005	.002 .005	5 10	>10	.1 .2	.2 .5	.001 .002	.002 .005	.0002 .0005	.0005 .0010	0	.2 .5
Taringa #2	20	<.01	.002 .005	.002 .005	<.005	0	0	>10	.2 .5	.2 .5	.001 .002	.0005 .0010	.0001 .0002	.0005 .0010	0	.5 1.0
Taringa #2	39	<.01	.002 .005	.001 .002	<.005	0	0	>10	.2 .5	.2 .5	.001 .002	.0005 .0010	.0001 .0002	.0002 .0005	0	.5 1.0
Taringa #2	55	<.01	.002 .005	.005 .010	<.005	.0002 .0005	0	>10	.5 1.0	.2 .5	.001 .002	.0005 .0010	.0005 .0010	.0002 .0005	0	.5 1.0
Taringa #3	2	<.01	.002 .005	.002 .005	<.005	.0005 .0010	0	>10	.2 .5	.2 .5	.001 .002	.0005 .0010	.0001 .0002	.0005 .0010	0	.5 1.0
Taringa #3	8	<.01	.002 .005	.001 .002	<.005	0	0	>10	.5 1.0	.2 .5	.002 .005	.0005 .0010	0	.0002 .0005	0	.5 1.0
Taringa #3	18	<.01	.01 .02	.01 .02	<.005	.0005 .0010	2 5	>10	.2	.2 .5	.001 .002	.002 .005	.0005 .0010	.0005 .0010	0	.5 1.0
Taringa #3	34	<.01	.002 .005	.002 .005	<.005	0	0	>10	.5 1.0	.2 .5	.001 .002	.0005 .0010	.0001 .0002	.0005 .0010	0	.5 1.0

The following elements were also looked for but not found:

Sensitivity limit	Elements
.00005	Ag
.0001	Be, Yb
.0005	Co, Ge, Ni, Pd
.001	Bi, Ga, In, Mo, Nb, Sn, V, Y, Zr
.003	Au, Pt
.005	Cd, Er, Gd, Ir, La, Os, Re, Rh, Ru
.01	Li, Nd, Sb, Sm, Tl, W
.03	Te, Zn
.05	As, Ce, Dy, Hf, Ta, Th, U
.5	K
1.0	Hg

Table 5.- Pumice analyses; elements determined by semiquantitative spectrographic method. Analyses by Paul Barnett, U. S. Geological Survey. Elements reported by percent ranges.

Element*	Gray pumice Matukerekere	Black pumice Hare Island	Element*	Gray pumice Matukerekere	Black pumice Hare Island
Si	> 10	> 10	Cr	.0001-.0002	.0001-.0002
Al	> 10	> 10	Cu	.0005-.0010	.001-.002
Fe	2.2-4.6	1-2	Ga	.0005-.0010	.0005-.0010
Ti	.2-.5	.2-.5	La	.005-.010	.005-.010
Mn	.05-.10	.05-.10	Mo	.001-.002	.001-.002
Ca	1-2	1-2	Nb	.005-.010	.005-.010
Mg	.5-1.0	.2-.5	Nd	.005-.010	.005-.010
Na	1-2	1-2	Pb	.0002-.0005	.0002-.0005
K	1-2	1-2	Sc	.0005-.0010	.0005-.0010
B	.001-.002	.001-.002	Sr	.05-.10	.02-.05
Ba	.05-.10	.05-.10	V	.001-.002	.001-.002
Be	.0002-.0005	.0001-.0002	Y	.005-.010	.005-.010
Ce	.01-.02	.01-.02	Yb	.0005-.0010	.0005-.0010
Co	.0002-.0005	.0002-.0005	Zr	.02-.05	.02-.05

*The following elements were looked for but not found: Ag, As, Au, Bi, Cd, Dy, Er, Gd, Ge, Hf, Hg, In, Ir, Li, Ni, Os, P, Pd, Pt, Re, Rh, Ru, Sb, Sm, Sn, Ta, Te, Th, Tl, U, W, Zn.

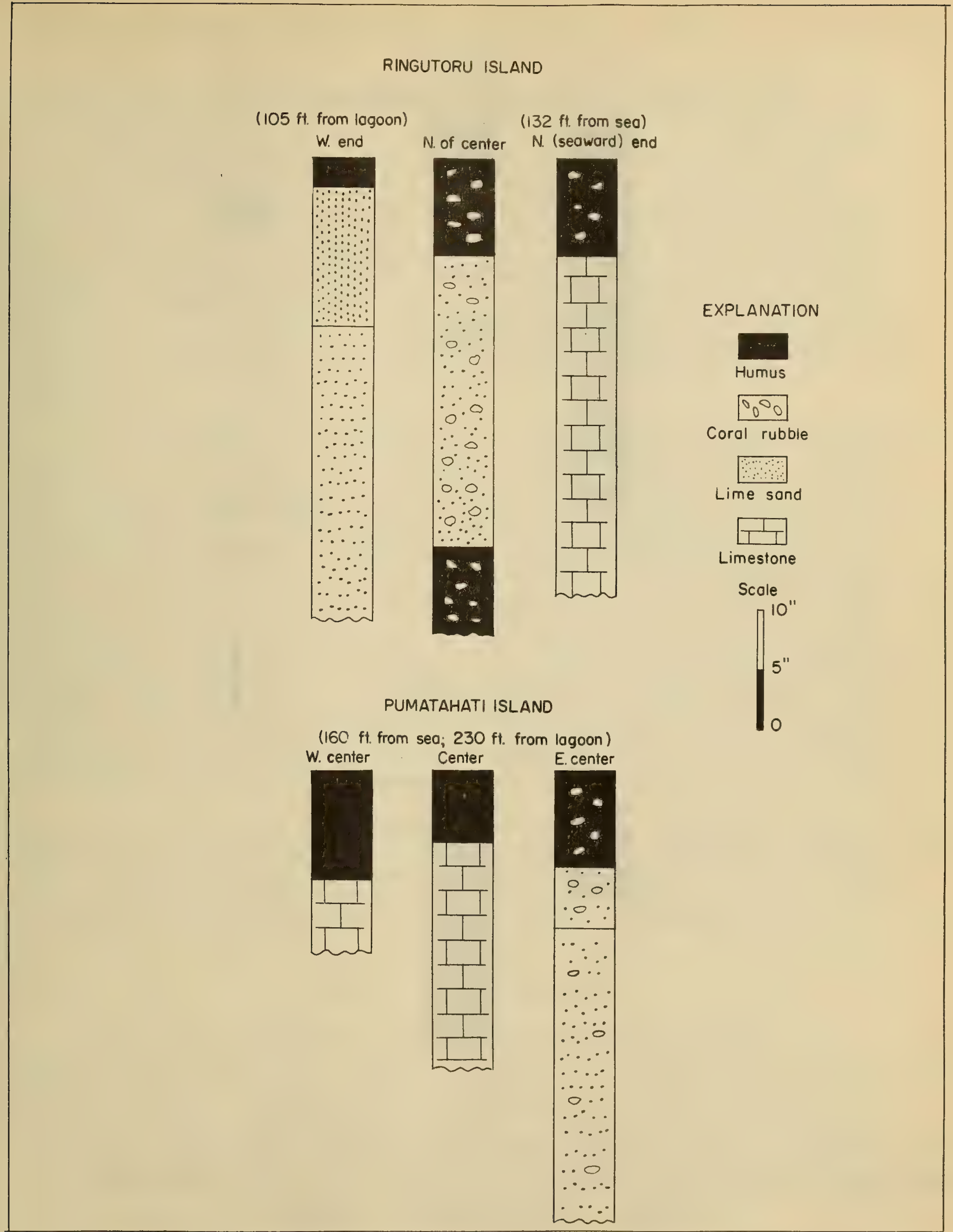
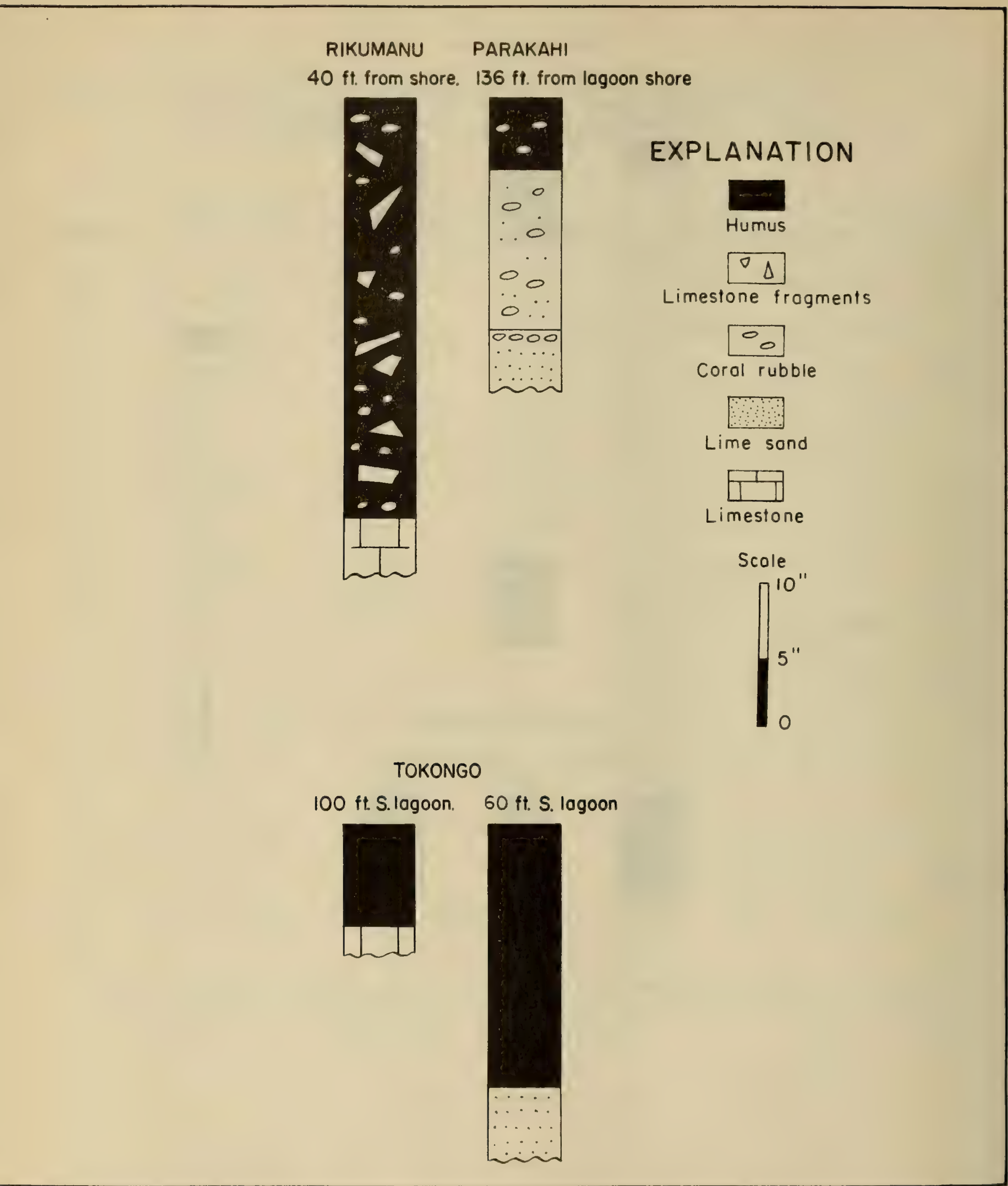


FIGURE 12 — TYPICAL SOIL PROFILES IN TEST PITS ON RINGUTORU AND PUMATAHATI ISLANDS



IGURE 13.— TYPICAL SOIL PROFILES IN TEST PITS ON RIKUMANU, PARAKAHI AND TOKONGO ISLANDS

construction. Several illustrations of this process, in various stages of development, are known; and the natives are fully aware of the possibilities of increasing the size of their islands by this method. One of the best examples of sedimentation resulting from the process is near the south end of Hare Island, where a small islet has been attached and completely incorporated into the main island (fig. 8). Remnants of a stone causeway about 150 feet long are still visible in the middle of the area though sediments have accumulated to a considerable height on both sides of it. Seaward from the causeway an area about 300 feet long has been entirely filled in by natural processes, locally with sand and elsewhere with mixed sand and rubble. Soil has not yet developed. On the lagoon side sand and rubble have been piled up on the shoreward part, leaving a depressed area inland toward the causeway; this low area is swampy and already has accumulated some black sticky mud.

According to soil nomenclature used on other atolls of the Pacific (Stone 1951, p. 19-37), most of the soil at Kapingamarangi probably should be classed as belonging to the "Shioya soil series." This is especially true where the soil has developed in the very young sediments on the lagoon sides of islands. In some places on the older, seaward parts of islands, development has gone beyond the Shioya stage and greater, more concentrated accumulations of organic material have resulted in a darker soil which perhaps should be assigned to the "Arno soil series." In these two soil types there is great textural variation both vertically and laterally. Such variations, as shown in test pits (figs. 12 to 15), include organic materials that are relatively pure and others that are mixed with lime sand, coral rubble, or limestone blocks. Because nearly all the soils are developed on surfaces above the water table that allow rain water to pass through rapidly and that are conducive to relative dryness, mangrove swamps do not exist and muck or peat is scarce. Only puraka pits and a few bomb craters where water accumulates permanently have an environment favorable to these soils.

Many illustrations of correlations between plant indicators and types of soil and sediment are apparent on Kapingamarangi. The constant association of Scaevola with sandy beaches and of Guettarda with coarse rubble ramparts or with small islets covered by rubble are examples. This subject has been studied in detail by William Niering and will be described by him.

DEVELOPMENT OF PHOSPHORITE

Phosphatic soils and rock phosphate or phosphorite occur at numerous places on various islands of Kapingamarangi Atoll. The soils appear to be very similar to other soils that are composed of lime sand and humus, but X-ray diffraction tests show that mineralogically they contain apatite in addition to calcite and aragonite and that a few samples consist of apatite only. The phosphorite or rock phosphate resembles in texture and structure the limestone from which it developed, but commonly it is very light in weight owing to high porosity. In many places it is various shades of brown, and in general has a powdery, earthy appearance.

The origin of the phosphorite from the guano of birds is attributed to phosphorization of salts in the guano, involving reactions with foraminiferal or coral limestone. According to Aso (1953, p. 19) the principal components of this type of phosphate normally are secondary calcium phosphate, $CaHPO_4$; tertiary calcium phosphate, $Ca_3P_2O_8$; and calcium carbonate, present in varying ratios. Thus, the phosphate probably represents a stage intermediate between fresh guano and tertiary calcium phosphate, the conversion taking place under the influence of organic acid and carbonic acid gas. The ease with which calcium carbonate is dissolved by phosphatic solutions is a significant factor in this process (Aso, 1953, p. 17).

The distribution of phosphatic soils and phosphorite at Kapingamarangi and the concentration of these products (table 6) appear to have a significant relationship to the history of island development. At Pumatahati Island, test pit 1 near the island center shows complete phosphorization of limestone in both soil and stratified rock to a depth of 2 feet or more (table 6). Test pit 2, farther east on the same island, shows only a little apatite present, and that is near the surface. Nevertheless, the fact that surface soil is affected in both places suggests recent development. High concentration in the central area is expectable, for this island is reported by the natives to have been the roosting place of large numbers of frigate birds for many years.

Varying concentrations of phosphatic soil are recognized on several islands other than Pumatahati. These include Taringa (table 6) and Werua (table 4) and probably others for which analyses have not been made. The localization of apatite near the soil surfaces on these islands suggests that its development may be relatively recent. Phosphorite comprising the stratified rock on several other islands, however, clearly is of considerable age, i.e., formed before the islands had migrated to their present positions. On Ringutoru and Rikumanu, for instance, high-level remnants of stratified rock considered to antedate the latest fall in sea level, and standing above areas of soil on the island margins, are highly phosphorized. On Hare, Nunakita, and Rikumanu, stratified rock that today is on the seaward shores, beyond the outer fringe of vegetation, and is periodically covered by high-tide waters, likewise is high in apatite (table 6). These deposits are interpreted as relicts from a time when they were in island interiors, such as the frigate birds inhabit today, and when birds in numbers frequented the areas.

GROUND WATER

General features.- The presence on most small islands of fresh or brackish ground water floating on the relatively heavy salt water within island rocks and the lens shape normally assumed by such bodies of fresh water have long been recognized by hydrologists. The name "Ghyben-Herzberg lens" commonly is used in referring to these lenses of fresh water (Stearns and Vaksvik, 1935, p. 237-239).

Most of the islands on Kapingamarangi Atoll contain ground water of varying degrees of freshness. On the larger islands this water is potable

Table 6.- Percentages of apatite as determined by X-ray diffraction analyses. Data from James Gude, U. S. Geological Survey.

Island	Stratigraphic Position	Depth (inches)	Apatite (percent)	Comments
Ringutoru	High-level remnant	0	50	Relict bedrock.
Rikumanu	High-level remnant	0	75	Relict bedrock.
Rikumanu	Stratified shore deposits	0	20	Relict bedrock.
Rikumanu	Stratified shore deposits	0	40	Relict bedrock.
Nunakita	Stratified shore deposits	0	30	Relict bedrock.
Hare	Stratified shore deposits	0	20	Relict bedrock.
Pumatahati	Soil, top	3	100	Pit 1, near island center.
Pumatahati	Upper bedrock	8	100	Pit 1, near island center.
Pumatahati	Lower bedrock	20	100	Pit 1, near island center.
Pumatahati	Top soil	4	2	Pit 2, eastern interior.
Pumatahati	Transition soil	11	2	Pit 2, eastern interior.
Pumatahati	Unconsolidated	22	0	Pit 2, eastern interior.
Taringa	Top soil	5	50	Well 2, near island center.
Taringa	Transition soil	25	0	Well 2, near island center.
Taringa	Coral rubble	40	0	Well 2, near island center.

and of sufficient quantity for domestic use. The natives have dug wells penetrating it in a number of places, but in general they prefer cistern water for drinking. This is fortunate, for the wells near the places of habitation are apt to be polluted. In the village on Touhou, water from the community well is used largely for washing purposes; much of it is carried in buckets to bath houses but some is used in the immediate vicinity.

Because of drouths the supply of cistern water becomes low from time to time and locally is exhausted. At such times the ground water of the islands constitutes an important supplementary supply of potable water. Factors that control the location, quality, and amount of this water are similar to those that have been described in connection with the ground water of other atolls (Cox, 1951; Arnow, 1954), but distinctive features of climate, lithology, and terrain are responsible for local variations and make desirable an analysis of the local water problems.

Objectives of investigation.- Ground-water studies on Kapingamarangi Atoll, made periodically during June, July and August of 1954, were conducted on four islands -- Taringa, Werua, Parakahi, and Hukuniu. These islands were selected partly because of accessibility but largely because they were considered representative of the principal island types. Taringa is an example of a moderately long but narrow (600 ft.) island with stratified rock forming the seaward shore and sand beaches the lagoon shore. Werua is similar but considerably wider (1000 ft) and with more variation in topographic character resulting from larger size. Parakahi is a small island (400 ft x 300 ft) the surface of which is formed entirely of unconsolidated sediments. Hukuniu is a very small island (250 ft x 150 ft) in which stratified rock forms all of the shores and also the surface, except for a thin mantle of humus in the interior.

The principal objectives of the ground-water investigation were to obtain data on (1) the depth to water in various parts of the islands, (2) the amount of change in water level as compared with tidal changes in adjoining sea and lagoon, (3) the amount of lag between the extremes of tide and the corresponding changes represented in well levels, (4) the effects of permeability in different types of rock and in unconsolidated sediment, (5) the variations in ground-water lenses resulting from differences in size of islands, and (6) the quality of the water resulting from various situations. All these features have a close relationship to the availability and usefulness of ground-water on Kapingamarangi.

Methods of study.- A series of eight wells -- three on each of the large islands and one on each of the small islands -- were dug by native labor to a depth below the lowest level of the water table for each area involved. Records were made of the types of sediment penetrated (figs. 14 and 15) and a staff gage was installed in each well for measuring water fluctuations. Three times during the summer hourly readings were made for 24-hour periods to obtain from this series of wells relative measurements of the times and extent of water fluctuations. Some water samples were analyzed in the field for salinity and pH. Others, representative of all the wells, were brought back to the U. S. Geological Survey in Denver, where analyses were made by John D. Hem.

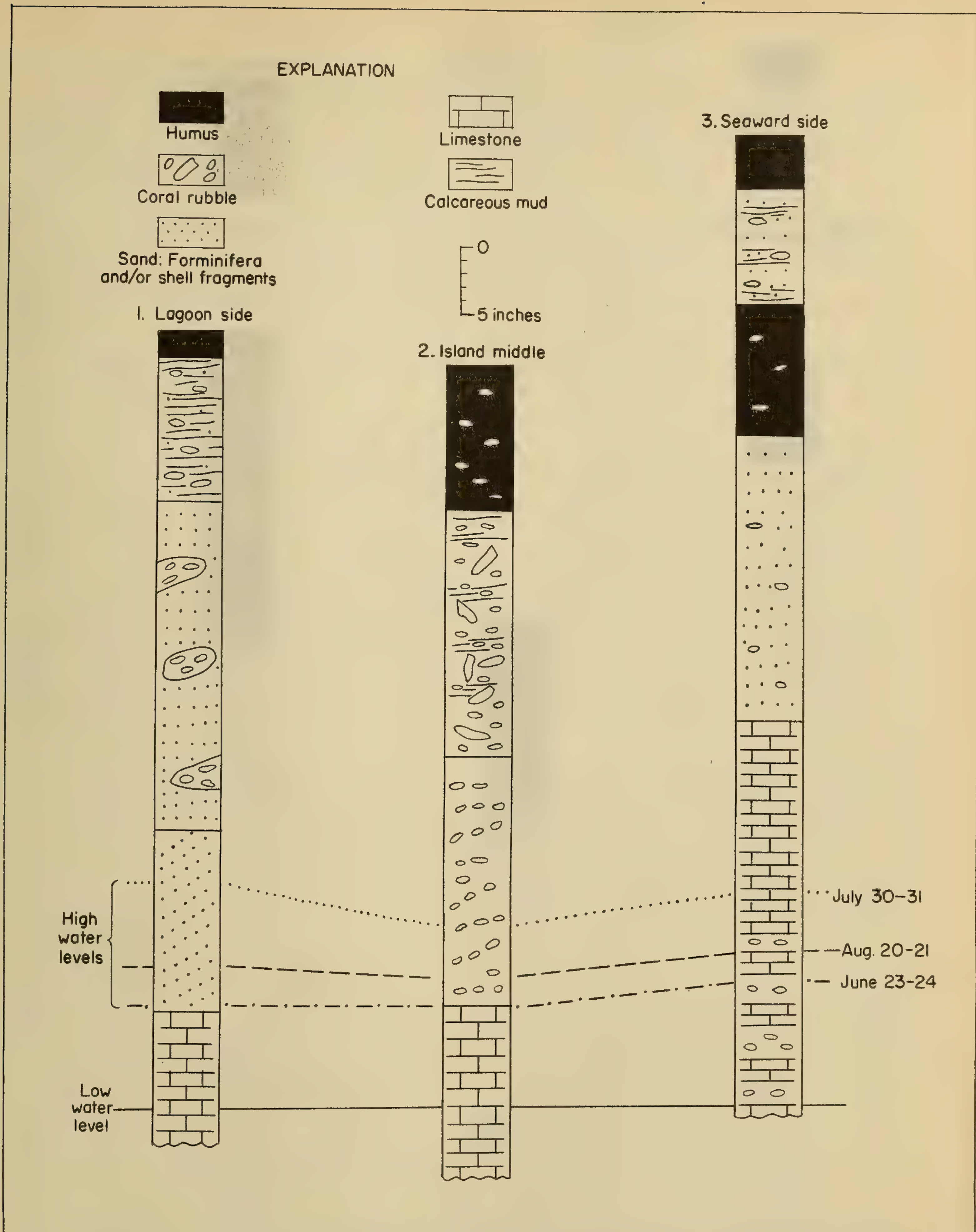


FIGURE 14— LITHOLOGY AND WATER LEVELS IN WELLS ON TARINGA ISLAND

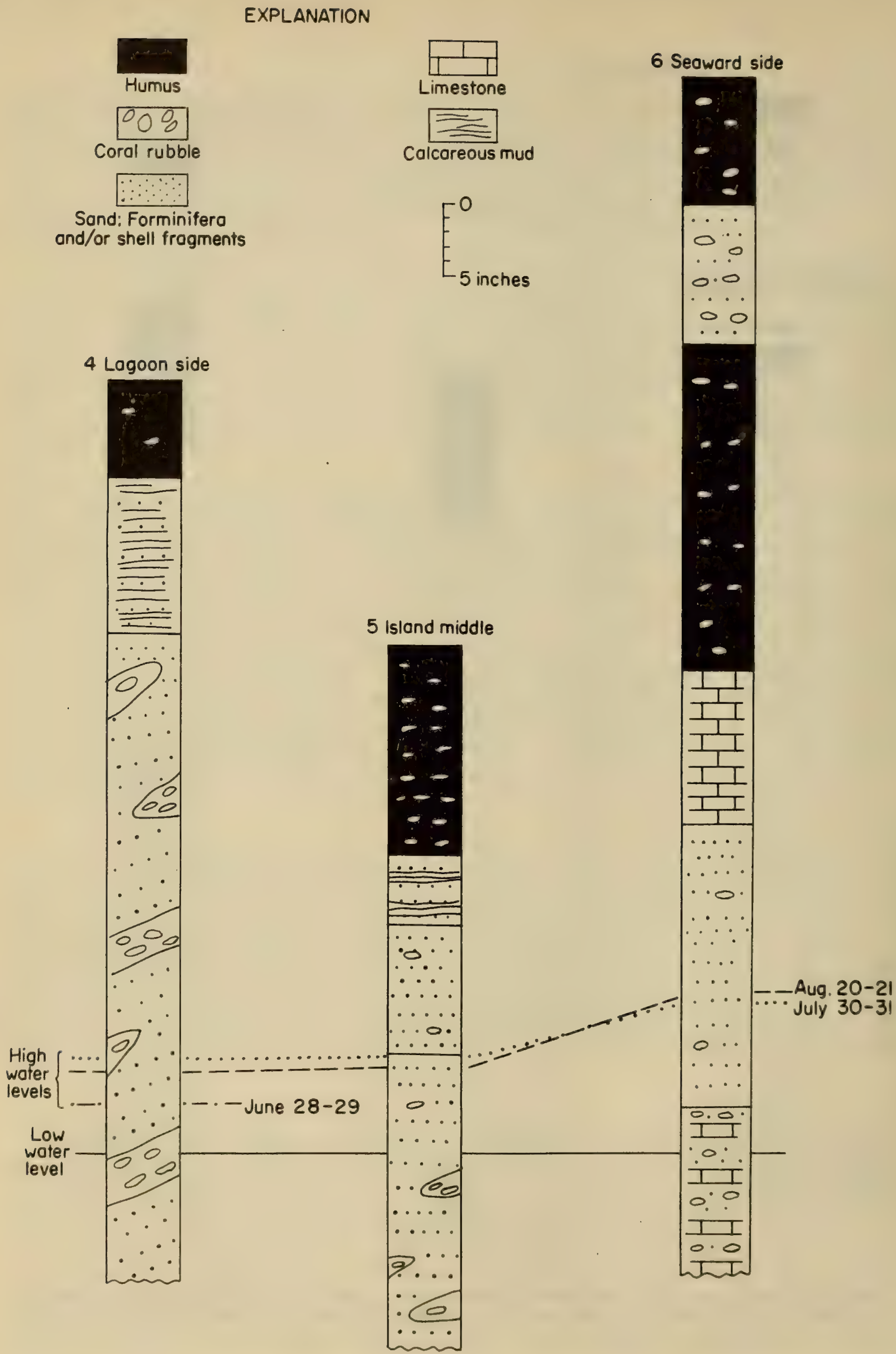


FIGURE 15 – LITHOLOGY AND WATER LEVELS IN WELLS ON WERUA ISLAND

The wells on both Taringa and Werua Islands were dug in a row across the islands from west (lagoon shore) to east (seaward shore) and about midway along the length (north-south dimension) of each island. Locations of wells are shown on maps (figs. 4 and 5). The spacing of the three wells relative to the coasts on these islands was as follows:

	Lagoon to well 1	Well 1 to well 2	Well 2 to well 3	Well 3 to sea
Taringa	68 ft.	250 ft	160 ft	125 ft
Werua	65 ft	500 ft	300 ft	125 ft

The single wells on the two small islands were dug near the centers. Locations were as follows:

	From lagoon (W) side	From sea (E) side	From north side	From south side
Parakahi	136 ft	288 ft	145 ft	156 ft
Hukuniu	100 ft	164 ft	91 ft	54 ft

The wells on Taringa and Werua Islands ranged in depth from 4 feet 2 inches to 7 feet 1 inch, depending on the depth to ground-water at its lowest stage. The two deepest wells were those adjacent to the seaward coast. They were not located on boulder ramparts but on lower ground inland from the ramparts. These wells were the most difficult to dig, for stratified rock was encountered in each a little more than halfway down.

Depth to ground water.- As stated in the Ghyben-Herzberg principle, the highest part of the fresh-water lens within the rocks of most small islands is somewhat higher than sea level adjacent to the island. Because the ratio of fresh- to salt-water density that controls this lens is approximately 40/41, it follows that the elevation of fresh water above sea level is slight on islands the size of those on Kapingamarangi. Cox (1951, p. 22) and Arnow (1954, p. 3) show that an average height of about a foot is to be expected on the islands that they examined in different parts of the Marshall group.

Equipment was not adequate to measure the elevation of ground-water lenses with respect to sea level at Kapingamarangi. It seems safe to assume, however, that the elevation on any of those islands does not exceed 10 to 12 inches and in most places is far less. Thus, the water level on those islands may be regarded as roughly equal to sea level, and the depth to water in any well is approximately equal to the elevation above sea level of the surface at the well site. Because the lagoon margins of islands commonly are slightly higher than the island centers and because the seaward margins are considerably higher than the lagoon margins, the depth to ground water normally is greatest near the seaward margins of the islands and least near the centers. Figures 14 and 15, using low-water level as a datum plane (not allowing for the increase in elevation in the island center that results

from the lens effect of the fresh water body), show the following depths to the highest recorded water level:

	Lagoon side	Middle island	Seaward side
Taringa	43 inches	43 inches	58 inches
Werua	48 inches	29 inches	66 inches

The figures in the preceding table probably are representative of depths required to reach the upper limits of water on all the larger islands at Kapingamarangi, but to reach the level of permanent water (low-water level) an additional 8 to 12 inches is required. Further, if wells are to be used for domestic purposes, allowances must be made for normal drawdown, for lowering due to periods of little recharge and for adequate storage, so additional depth is necessary. The depth should not be greater than necessary to achieve the above objectives, however, or salt-water contamination of the wells may occur.

On the very small islands at Kapingamarangi, the water table commonly is closer to the surface than on Taringa and Werua. This is due to lower topography. However, the amount of fresh water (if present at all on these small islands) normally is much less and the degree of salinity higher than on islands with large recharge surfaces, as shown by the wells on Parakahi and Hukuniu Islands.

Variations in water level.- Fluctuations in water level in islands like those of Kapingamarangi Atoll are principally of two types. In one the changes are gradual and are the result of increases or decreases in the amount of recharge; in the other the movement is observable from hour to hour and results from rising and falling tides that cause the salt water under the fresh water lens to go up or down. Fluctuations due to gain or loss in recharge were not detected during the period spent on Kapingamarangi Atoll, though doubtless such changes were continuously affecting the water levels of all islands, especially the very small ones. On the other hand, significant data were obtained on the effects of tide on ground-water levels.

Figures 14 and 15 show the total rise and fall of water levels in the wells on Taringa and Werua Islands, respectively, as shown by readings taken on June 28, July 30, and August 20. The low-water level for each well, as measured with respect to the well bottom, was essentially the same for the three dates. The high-water levels, however, show marked differences, especially on Taringa, and these differences are directly related to tidal fluctuations as indicated by tide records. The amount of rise in the two wells located in island centers is slightly to moderately less than that of the wells on the corresponding island margins. This difference undoubtedly results from incomplete readjustment of the fresh-water lens, due to increased friction from distance of travel, during the short intervals between tidal changes. It supports the principle, pointed out, for example, by Cox (1951, p. 14), that fluctuations in the water table of small islands are inversely proportional to distance from the coast.

Lag in rise and fall of ground water.- The elapsed time between attainment of high or low stage by the tide in waters adjacent to an island and the attainment of a corresponding high or low level by the ground waters in the island is variable according to the size of the island, the permeability of rock or sediment involved, and other lesser factors. In any event, this elapsed time is represented by a definite lag, which on Taringa Island was 3 to 4 hours and on Werua 4 to 5 hours (figs. 16a, 16b, 16c, 17a, 17b, 17c). On the small island of Hukuniu, however, there was virtually no lag between the time of high tide and high-water level (fig. 18a and 18b). This is interpreted as primarily the result of high permeability, as will be discussed later, rather than merely the small size of the island.

Analysis of the charts showing tide and well fluctuations (figs. 16, 17, 18) shows that the lagoon tidal variation is consistently greater than the variation on the seaward side of the islands, but that in the areas studied, the high and low tides arrive in both places at about the same time. Water levels in the wells on each island likewise show differences in amount of fluctuation, but on each island they reach their peaks at approximately the same time. These data suggest that differences in permeability as well as in distances from the shore and in tidal fluctuation at the shore are responsible for differences in the amount of rise and fall of the water table in any particular part of an island. Thus, in these small islands the fresh-water lens acts as a unit insofar as the time of rise and fall is concerned.

Relative permeability of sedimentary materials.- An asymmetry in the permeability of atoll islands has been indicated in the work of numerous geologists (Cox, 1951, p. 19). In most islands the lagoon shores are composed of beach sands, whereas the seaward shores are composed of stratified rocks, boulder ramparts, or both. The fine-grained sediment of the lagoon side is far less permeable than the coarse detrital fragments of the rampart or the cavernous limestone that constitutes much of the stratified rock. Fluctuations in water table on atoll islands appear to be proportional to the permeability of the sediment or rock through which the water moves.

On the islands of Taringa and Werua the seaward coasts are formed of stratified rock up to and above high-tide level and of narrow boulder ramparts above the rock. The ramparts are not significant insofar as the movements of the fresh water lenses are concerned, for, as illustrated in well profiles, all of the ground-water movement on this side of the islands is within the stratified rocks. Furthermore, water from wells on the seaward side is definitely brackish, mostly not potable, which suggests that it enters through open cavities or cracks with free circulation rather than by the slow percolation that constitutes intergranular movement in the sands. In contrast, ground water on the lagoon sides of these islands is fresh and drinkable almost to the beaches.

Parakahi and Hukuniu illustrate the effects of permeability on the ground water of very small islands. Well levels on Parakahi show approximately the same lag behind tide fluctuations as represented in wells of the larger islands. The water, which is potable, must enter through sand deposits from any direction. In contrast, water level in the well on Hukuniu

Island, which is formed almost entirely of stratified rock, reaches its high and low points essentially at the same times that high and low tides arrive. Furthermore, the salinity of the water in this well is close to that of sea water -- again suggesting easy access through large channels.

Effects of island size on lens.- Observation wells in the centers of the two very small islands -- Parakahi (400 ft x 300 ft) and Hukuniu (250 ft x 150 ft) -- suggest that, on these islands at least, permeability of the rock or sediment, rather than size of the island, controls the amount of water-level rise and fall. Figure 18 shows that on Parakahi the rise is comparable to that of wells dug in similar sediments on the larger islands, whereas on Hukuniu, where cavernous stratified rock is involved, the rise is considerably greater, even approaching in amount the corresponding total rise of the tide.

The real significance of island size in regard to the fresh-water problem is whether or not a lens can develop and, if developed, can be maintained in a particular area. Because continued operation of a lens depends in large measure on the amount of recharge, a sizable surface area for catching precipitation and a sufficient amount of precipitation are basic. In considering how small an island may maintain a fresh-water lens, Parakahi Island, in a region of only moderate rainfall, is noteworthy for having a lens of fresh, potable water. Hukuniu, which is still smaller, has highly saline water but this may be due as much to contamination from free circulation through open channels in limestone as to small size of the island. Thus, only a rough qualitative measure of the minimum size requirement, furnished by the example of Parakahi, is available for Kapingamarangi Atoll.

Quality of the ground water.- Water samples collected on August 20, 1954, from each of the eight test wells and analyzed by the U. S. Geological Survey are summarized in table 7.

Data presented in table 7 illustrate that well waters from Taringa and Werua Islands are progressively higher in chemical components, total hardness, and percent sodium from the lagoonward to the seaward side of each island. This trend almost certainly is related to the amount of mixing with sea water in each place and probably results from differences in permeability of island sediments and rocks. The cavernous nature of rock beds on the seaward sides apparently allows relatively greater mixing than is possible in the intergranular spaces of sands on the lagoonward sides.

Comparison of water from the two small islands -- Parakahi and Hukuniu -- shows differences similar to those noted from one side to the other of the large islands, but contrasts are greater. These contrasts apparently also result from variations in permeability and in degree of mingling with sea water. Water from the Parakahi well illustrates relatively poor mixing; that in the Hukuniu well has nearly the composition of sea water.

The hardness of the well waters of Kapingamarangi Atoll undoubtedly reflects contributions of calcium and magnesium from limestone and lime sand. The hardness increases across Taringa and Werua from lagoon to sea, reflecting an increase in the degree of mixing of ground water with sea water.

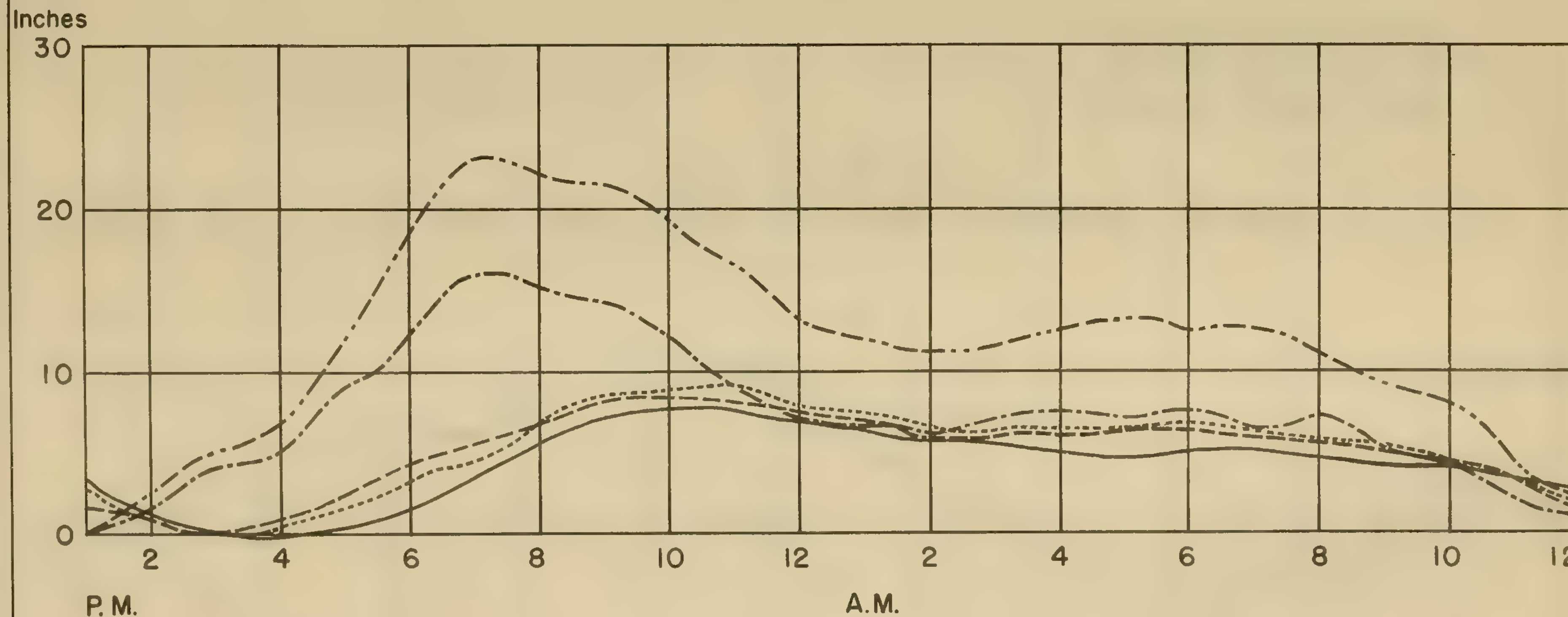


FIGURE 16a TIDE AND WELL FLUCTUATIONS, TARINGA ISLAND
JUNE 23-24, 1954

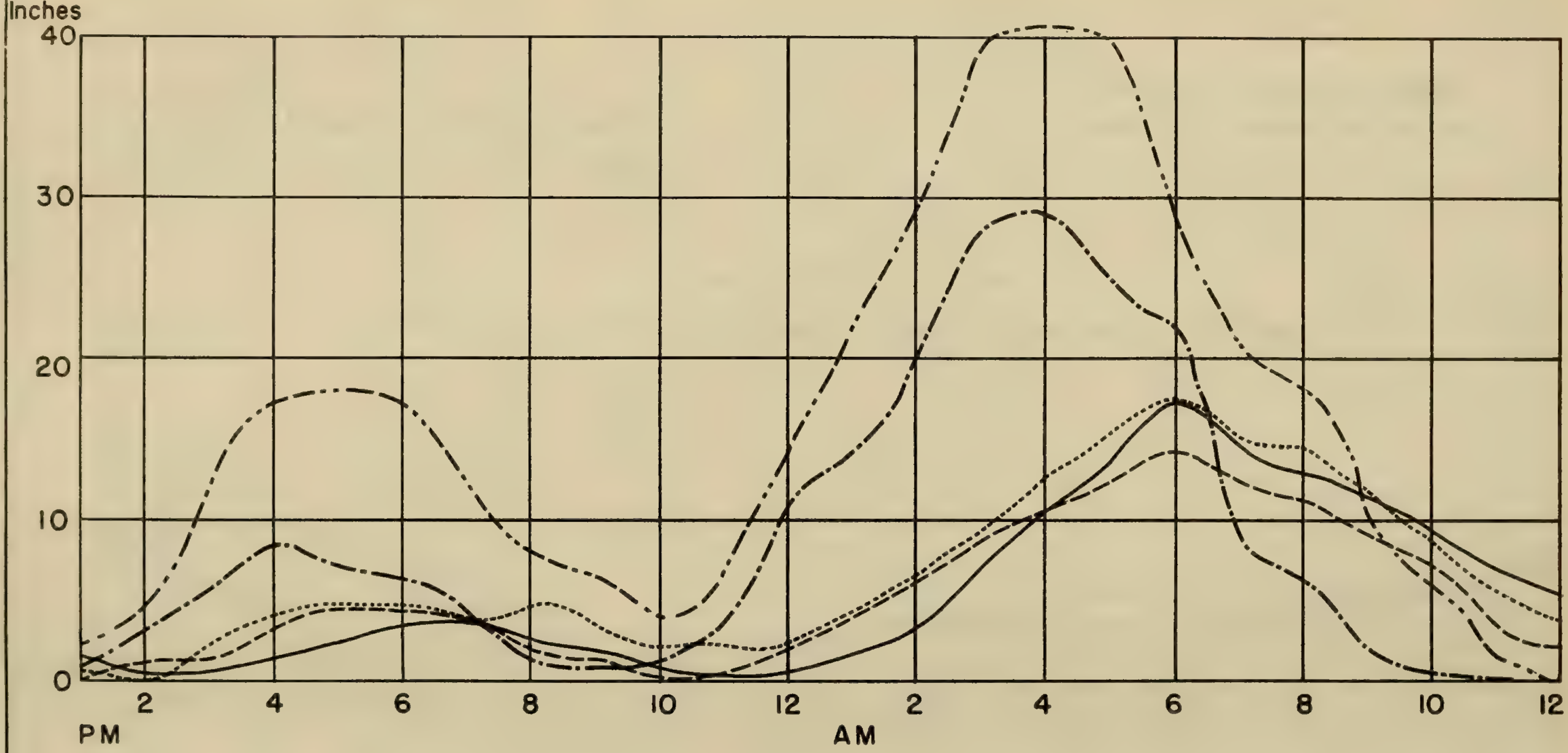


FIGURE 16b TIDE AND WELL FLUCTUATIONS, TARINGA ISLAND
JULY 30-31, 1954

—.—.— Tide on seaward shore
— — - - Tide on lagoon shore
——— Well #1, Lagoon side
- - - - Well #2, Center of island
.... Well #3, Seaward side

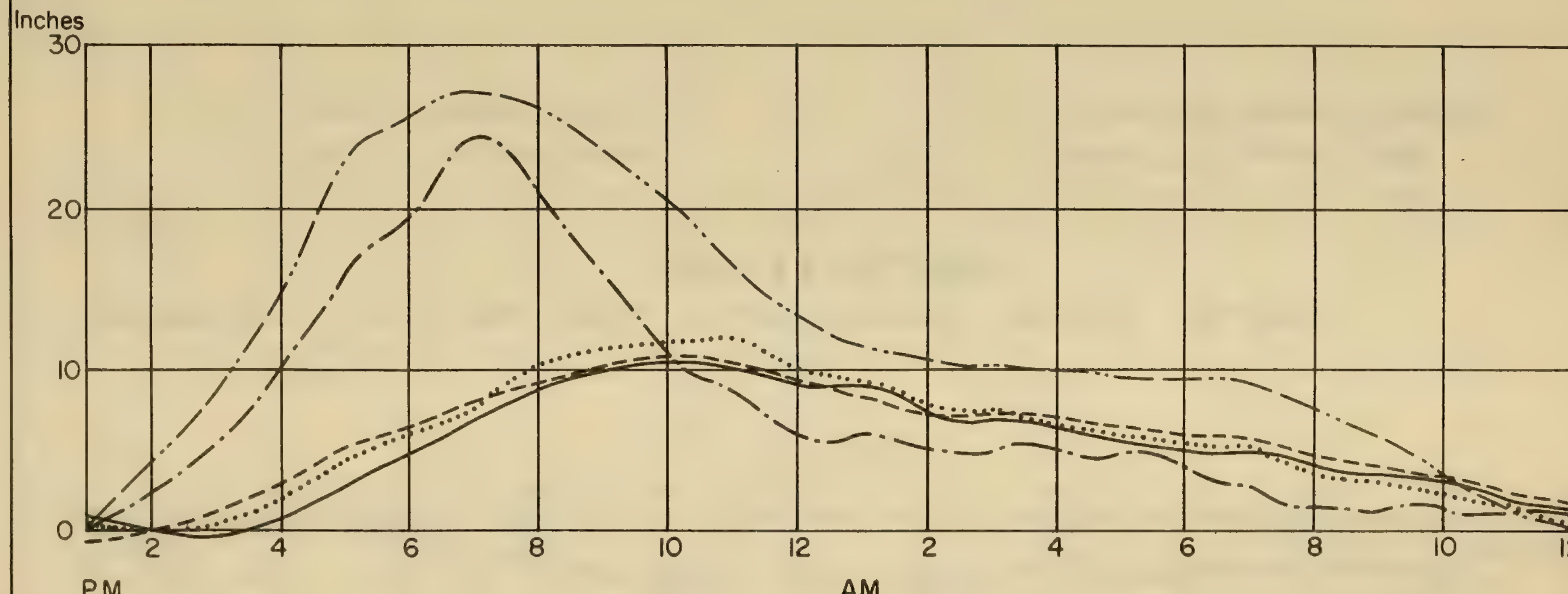


FIGURE 16c TIDE AND WELL FLUCTUATIONS, TARINGA ISLAND
AUG. 20-21, 1954

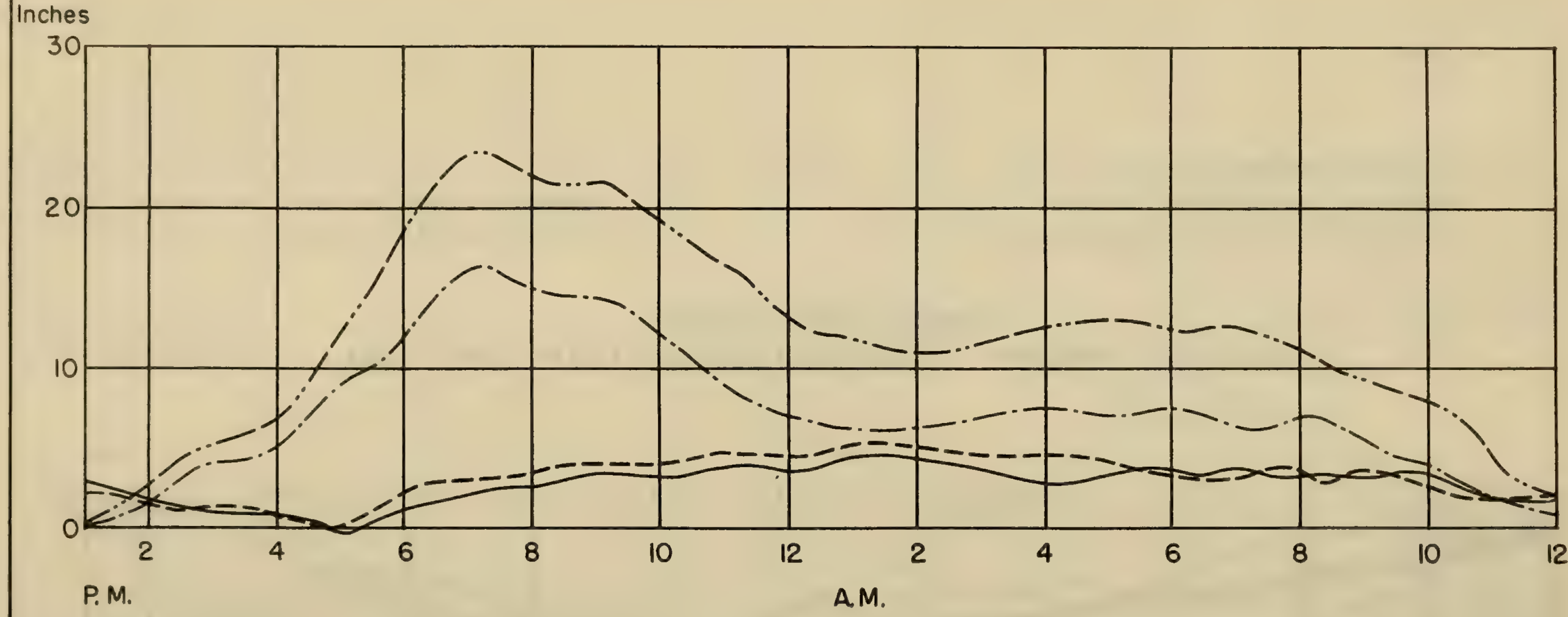


FIGURE 17a–. TIDE AND WELL FLUCTUATIONS, WERUA ISLAND
JUNE 23–24, 1954

—·— Tide on seaward shore
——·· Tide on lagoon shore
—— Well #4, Lagoon side
- - - - Well #5, Center of island

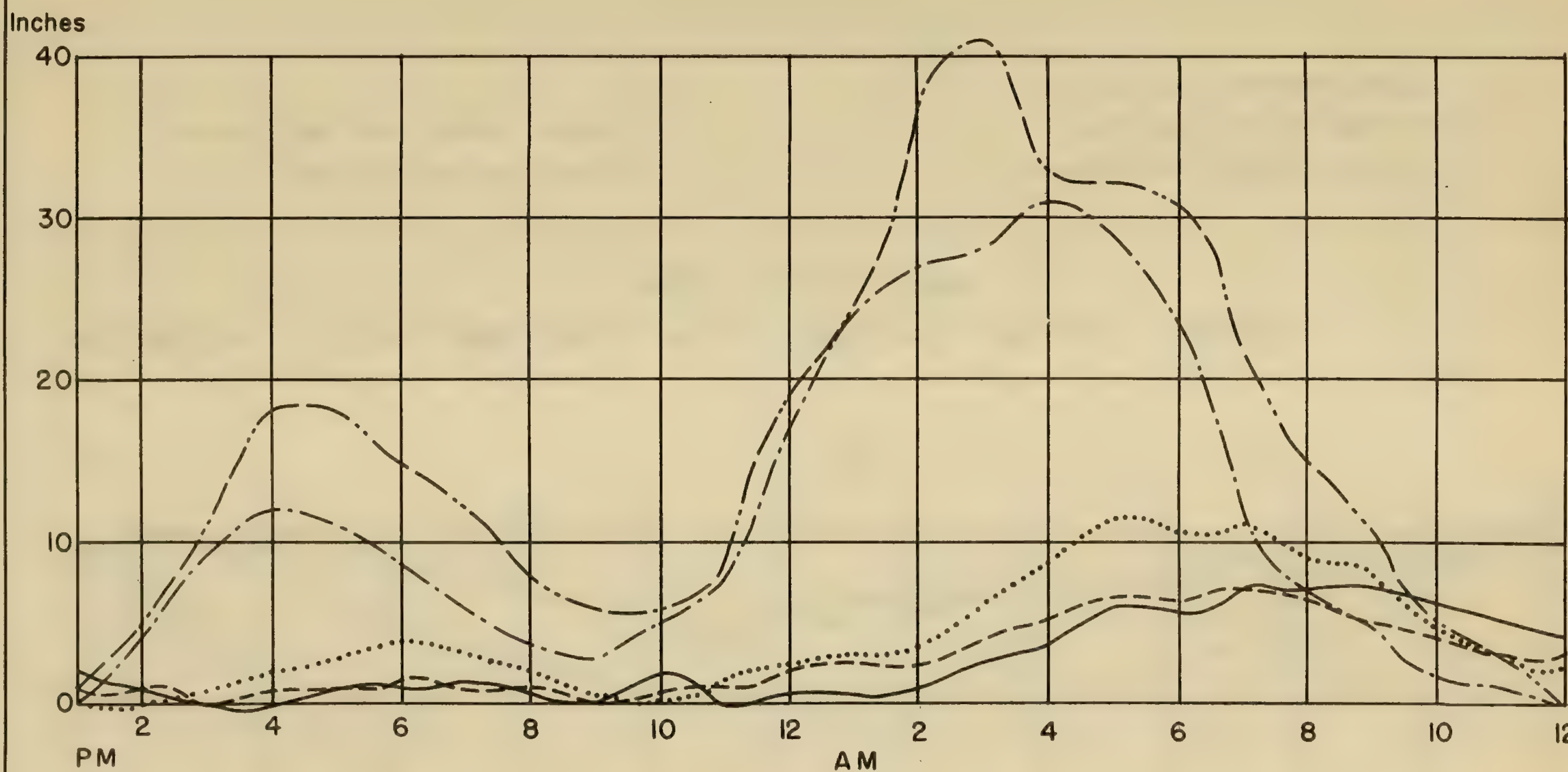


FIGURE 17b TIDE AND WELL FLUCTUATIONS, WERUA ISLAND
JULY 30-31, 1954

—·—Tide on seaward shore
——··Tide on lagoon shore
———Well #4, Lagoon side
- - - - -Well #5, Center of island
· · · · · ·Well #6, Seaward side

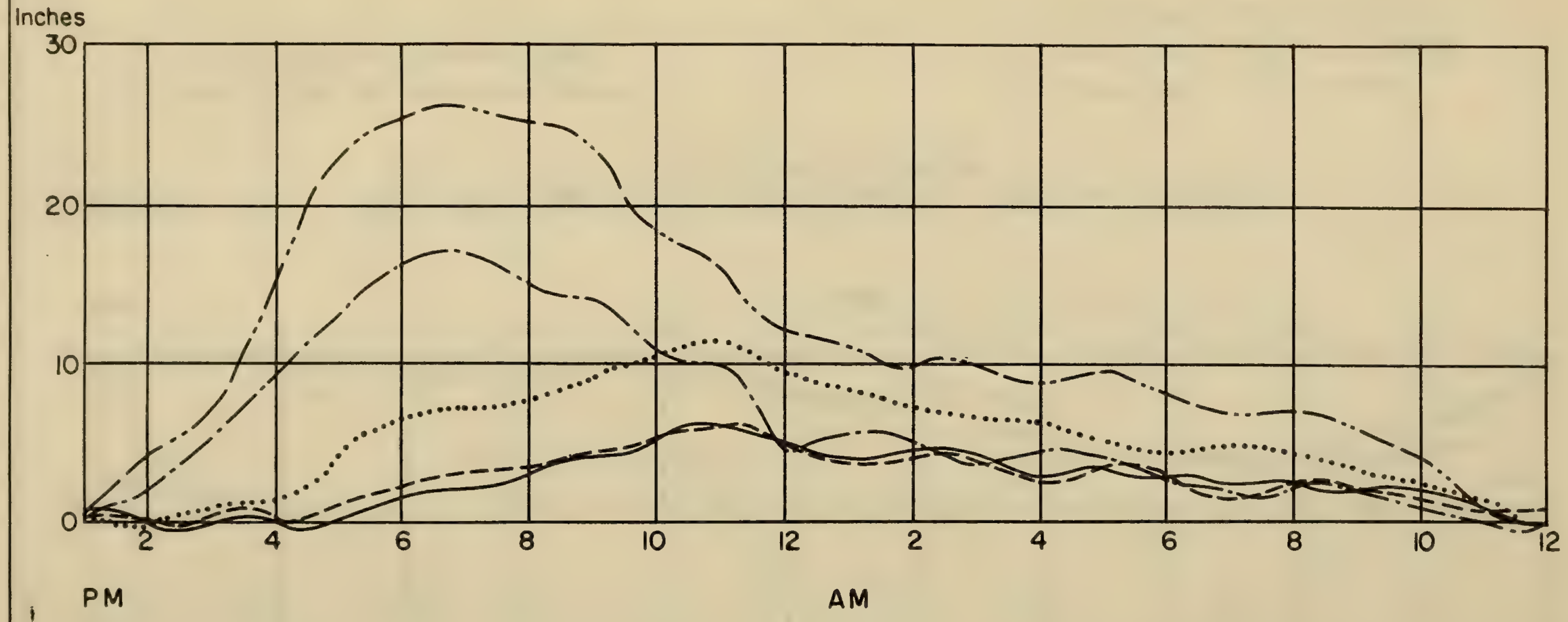


FIGURE 17c TIDE AND WELL FLUCTUATIONS, WERUA ISLAND
AUG. 20-21, 1954

—·—Tide on seaward shore
——··Tide on lagoon shore
———Well #4, Lagoon side
– – – –Well #5, Center of island
·······Well #6, Seaward side

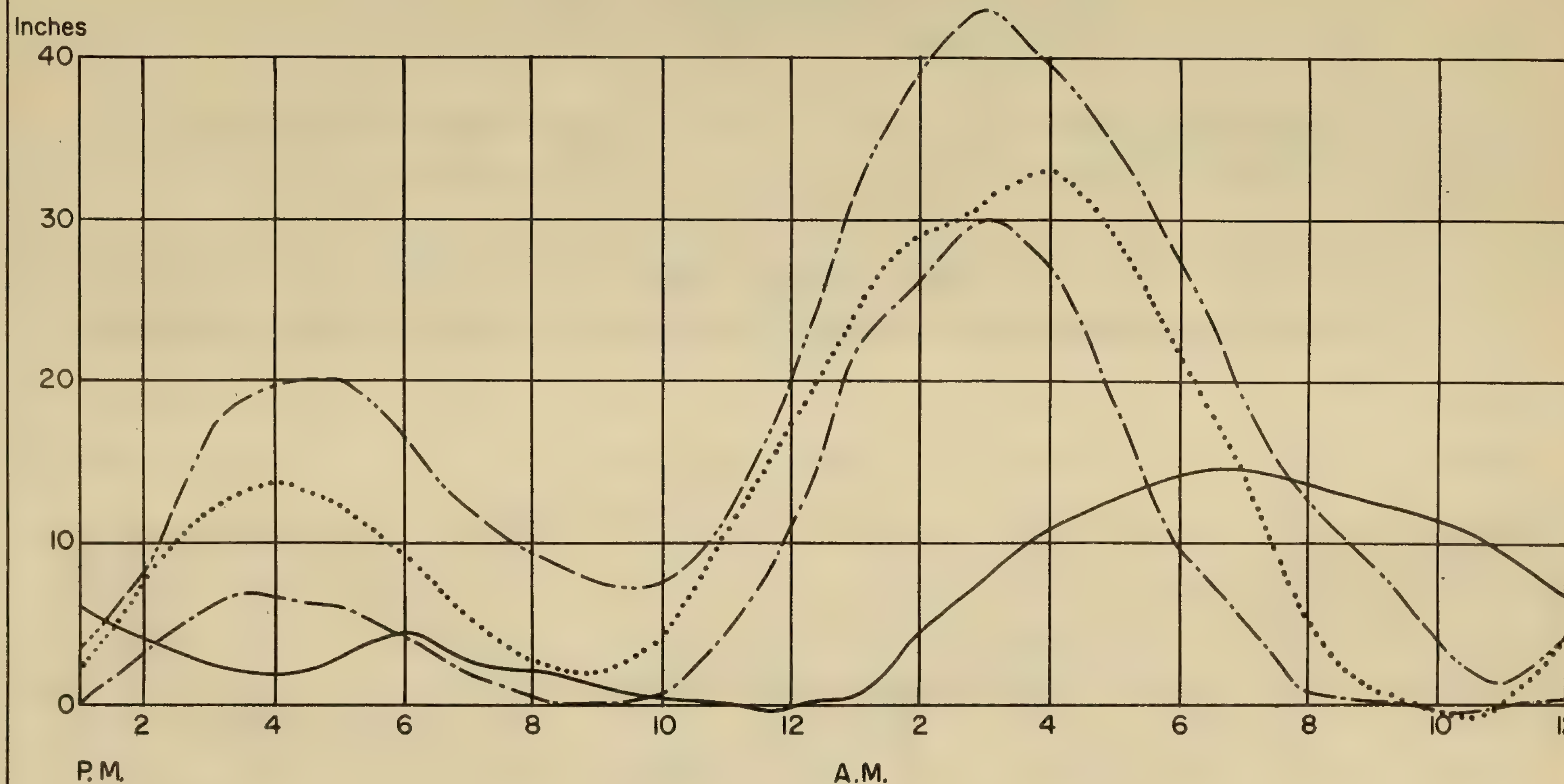


FIGURE 18a—. TIDE AND WELL FLUCTUATIONS, HUKUNIU AND PARAKAHI ISLETS
JULY 30-31, 1954

—·—Tide on seaward shore
——··Tide on lagoon shore
———Well #7, Parakahi
······Well #8, Hukuniu

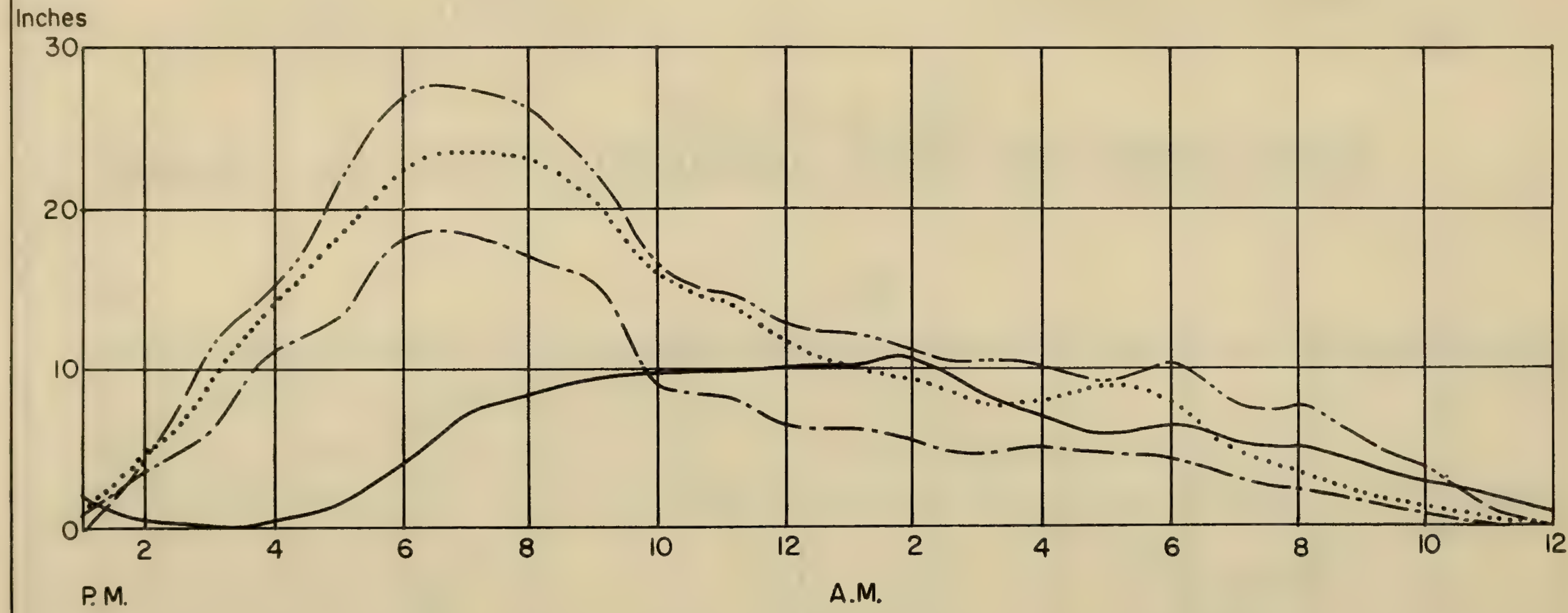


FIGURE 18b TIDE AND WELL FLUCTUATIONS, HUKUNIU AND PARAKAHI ISLETS
AUG. 20–21, 1954

—·—Tide on seaward shore
——··Tide on lagoon shore
——Well #7, Parakahi
······Well # 8, Hukuniu

Table 7.- Analyses of water samples from test wells and comparative data for normal sea water. (Analyses by U. S. Geological Survey)

	Taringa			Werua			Parakahi	Hukuniu	Normal sea water
	1	2	3	4	5	6	7	8	
Chemical components (ppm)									
Calcium (ca)	89	174	255	132	194	368	258	517	400
Magnesium (mg)	24	63	249	12	13	204	54	1,160	1,270
Sodium (Na)	38	560	2,010	22	23	1,580	400	9,390	10,560
Potassium (K)	2.4	18	75	3	2.4	55	12	359	380
Sulfate (SO_4)	16	4.1	459	1.2	4.1	288	30	2,290	2,650
Chloride (Cl)	55	1,100	3,810	20	18	2,980	875	17,500	18,980
Physical characteristics									
Hardness (ppm)	320	693	1,660	379	538	1,760	866	6,060	6,215
Percent sodium*	20	63	71	11	8	65	50	76	79

*Percentage of sodium among the principal cations (sodium, potassium, calcium, and magnesium), all expressed as chemical equivalents.

These relationships are illustrated by the fact that calcium is much higher than magnesium in the near-lagoon samples, reflecting solution of calcium carbonate and relatively little mixing with sea water, whereas calcium exceeds magnesium only moderately in the near-sea samples, reflecting mixing with sea water, which has a proportionately higher magnesium content.

The hardness of water from wells on the lagoon sides and in the island centers ranges between 300 and 700 ppm, so they are much higher than for soft waters ($<$ 50-60 ppm) as recognized in the United States. These waters would require "water softeners" for domestic use in America. They are similar in quality to waters from the northern Marshall Islands recorded by Arnow (1954, p. 7).

Water samples from test wells on Taringa and Werua Islands were checked at various times during the summer for PH and temperature. The PH readings ranged from about 7.0 to 7.5, and those from the relatively brackish waters of wells on the seaward side were consistently high, apparently reflecting a slight alkaline increase from sea water mixing. Temperature readings for all well waters were 27.5° to 28° C (81.5°-83° F) in the early morning, but they commonly rose 1° or 2° C during the warmer part of the day.

Water from wells on the lagoon margins of islands is generally more potable than that from other parts and is easier to reach by digging. Probably all wells thus situated will furnish water of good quality which, if protected from pollution, can be used to advantage by the Kapingans. The U. S. Public Health Service recommends 250 ppm of sulfate (SO_4) and the same amount of chloride (Cl) as upper limits for water used in normal domestic consumption, although water considerably higher in these components may be used without apparent harm by people who have become adjusted to it. Water from the island centers is moderately good, but that on the seaward sides is too brackish to be acceptable.

NEAR-SHORE CURRENTS

Currents moving along the shores of the Kapingamarangi islands are, in part, normal longshore currents generated by waves and, in part, the results of tides. They contribute to the work of erosion and deposition; also they are significant in maintaining ventilation within the lagoon, introducing and circulating new sea water with each rise in tide. The tide rises 6 to 13 inches higher within the lagoon than it does on the seaward sides of the islands (figs. 16, 17, and 18), probably because the passes between islands form constrictions that limit the movements of water entering and leaving the lagoon.

In order to obtain specific data on the movements of near-shore currents, records were tabulated on the direction and relative rates of movement with respect to nine islands (figs. 19 and 20). Three of these islands -- Nunakita, Torongahai and Ringutoru -- are in the northern section of the atoll, four -- Werua, Matiro, Hare, and Taringa -- on the eastern side, facing the dominant wind direction, and two -- Pumatahati and Matukerekere -- on the southern arc. To observe currents, fluorescein dye, which produces an orange color readily observable even at a distance, was poured in the water. Movements recorded at times of both rising and falling tides were plotted for contrast.

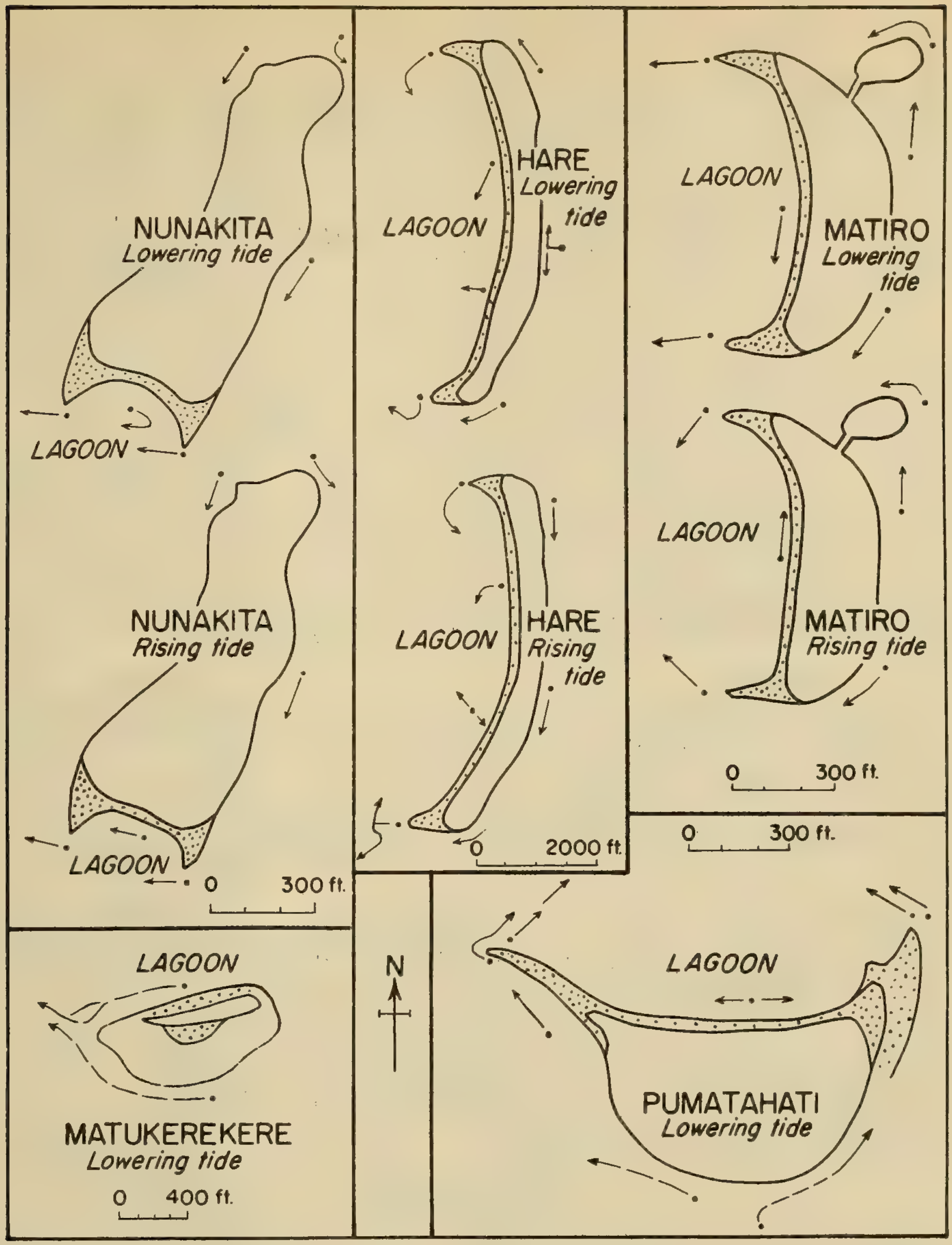


FIGURE 19.-NEAR-SHORE CURRENTS OF 2 SOUTHERN, 2 EASTERN AND 1 NORTHERN ISLANDS OF KAPINGAMARANGI

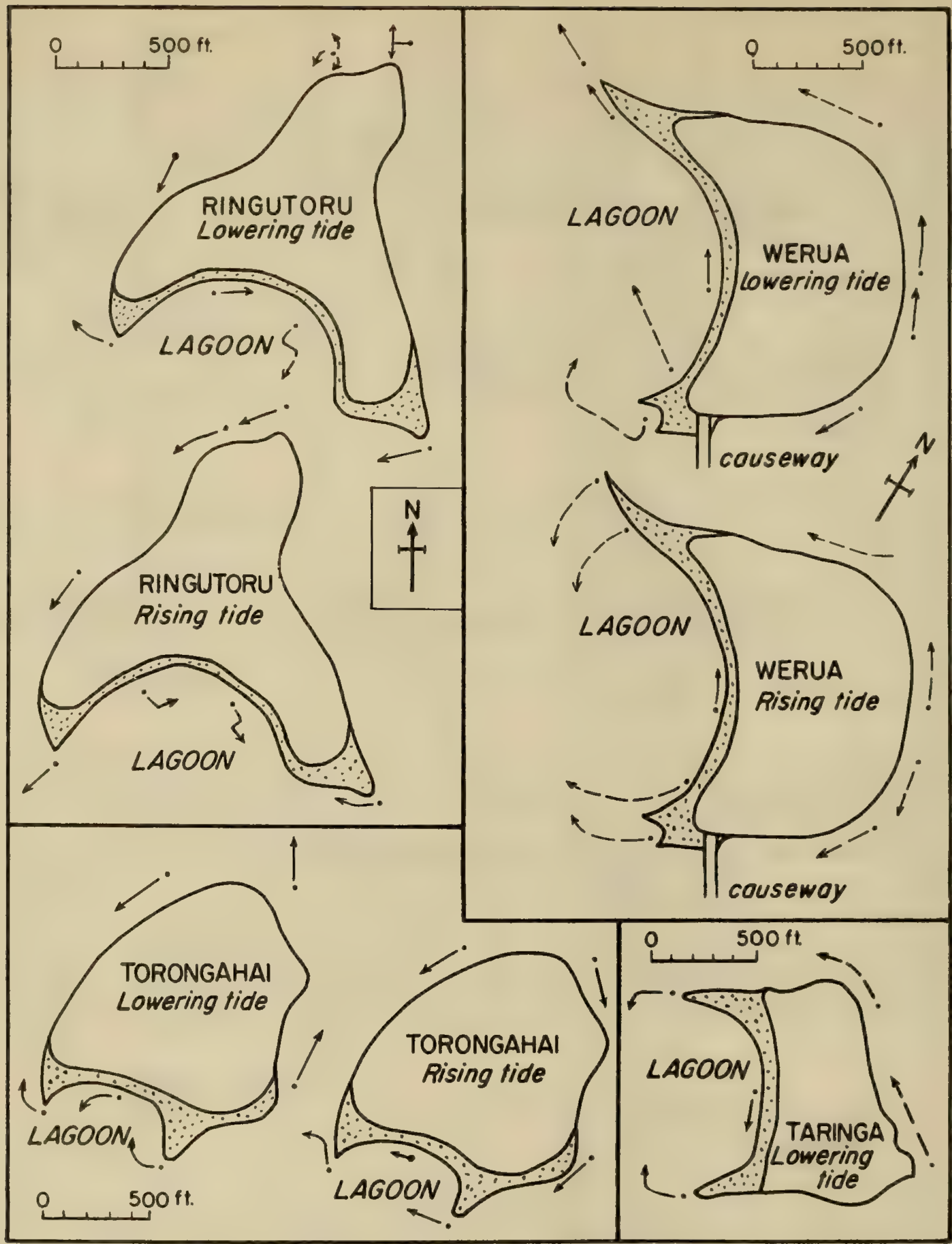


FIGURE 20.- NEAR-SHORE CURRENTS OF 2 EASTERN AND 2 NORTHERN ISLANDS OF KAPINGAMARANGI

The results of observations on near-shore currents as summarized in figures 19 and 20 show that on the seaward sides of most islands tidal currents normally move in opposite directions from a central point. During rising tides, however, longshore currents may develop with sufficient strength to direct all movement in one direction. The maps also show that on the concave lagoon sides, near the sand beaches, which are protected by horns or bars at the island extremities, movement of currents is extremely small at most times and has no dominant direction.

The most significant current movements adjacent to islands are those passing along the sides between islands. These are especially effective during rising tides. Such currents consistently travel toward the lagoon, moving clastic sediments and building rubble and sand bars out into the lagoon from the ends of each island. Furthermore, between the bars of adjacent islands these currents produce submerged deltas that protrude well out into the lagoon. The deltas are prominent in airplane photographs and are conspicuous even from a boat; normally they are composed dominantly of coral rubble in their headward parts and of foraminiferal sand in deeper waters beyond.

Because bare reef flats and little sand occur seaward of the Kapingamarangi islands, [1] relatively little sediment has accumulated on this side.

1/ This is in contrast to the conditions on Nukuoro and certain other atolls where Foraminifera (Calcarina) live in abundance on the reef flat outside the islands and form extensive sand deposits.

Shores at and below sea level are largely of stratified rock, which shows the effects of planation as should be expected from known current trends. The few lime sands that wash into this area normally do not remain but are moved along by currents and waves through the gaps between islands and thence into the lagoon. Even coral rubble from the reef edge, which is introduced in considerable amounts, appears to be transitory with respect to most seaward shores. Only the ramparts of boulders or rubble that stand above high-tide level and are formed by the waves of occasional large storms form significant deposits on seaward parts of the islands.

In the near-shore waters on the lagoon sides of islands, protected from the prevalent easterly winds by the islands themselves and from tidal currents by the horns or bars at island extremities, the normal, extremely weak and variable currents seem incapable either of depositing or of removing sediments of the beach. Most of these beaches are of foraminiferal sand and the species represented appear to live in the shallow waters nearby, but their accumulation and that of coral rubble as found at Hare and some other islands probably result from the occasional reversals in wind direction, which bring waves from west to east across the lagoon. These wind reversals result in a considerable piling up of water and sediment against lagoon shores of the islands.

The island of Pumatahati, on the southern rim of the atoll and near the western end of its islands, is unique in that its lagoon beach is formed almost entirely of coral rubble rather than sand and in that it has a well-developed rubble rampart on the lagoon side (fig. 9). Both of these features can be explained only as the results of the action of large waves

caused by strong winds. Furthermore, the winds must have come from east to west across the lagoon, for the source of rubble on the rampart and the greatest concentration of rubble on the beach are at the eastern end. Such features developed on this island and not on others probably because of its far westerly position on the southern reef.

SEDIMENTATION IN THE LAGOON

The lagoon at Kapingamarangi covers an area of about 15.5 square miles and has maximum dimensions of 5 by 6 nautical miles (Nugent, 1946, p. 755). Although it is roughly circular in plan, its symmetry is far from perfect because of an almost straight southwestern side. Profiles of the lagoon bottom, disregarding the many irregularities caused by patch reefs that rise from it, are those of a shallow basin (fig. 21). Even with the greatly exaggerated vertical scale used in the sections, the slope appears gentle, and sections of near-shore areas (fig. 22) and of Manin knoll (fig. 23), made with the same vertical and horizontal scales, demonstrate the low-angled slopes on which sediments are accumulating.

The deepest parts of the lagoon, in the north-central and east-central areas (fig. 24), are recorded as 43 fathoms on U. S. Navy Hydrographic Office Chart 6042. The greatest depth measured by the writer in more than 200 soundings was 40 fathoms (240 feet); however, this depth was reached in at least five places, suggesting a relatively flat bottom. Because of the slightly asymmetrical distribution of the deepest areas, resulting in gentle slopes on the south and west sides of the lagoon, Nugent (1946, p. 756) postulated that Kapingamarangi "is apparently tilted to the northeast." This feature of distribution can be equally well explained in other ways, however, and the relative narrowness of the southwest arc of the atoll as compared to the northeastern arc argues against the postulate.

In order to obtain a detailed record of bottom sediments in the lagoon, samples were collected systematically along many lines forming a modified grid pattern. Both grab samplers and bottom drags were employed during the work, and in relatively shallow waters samples were obtained by diving. Approximately 250 samples, representative of essentially all parts of the lagoon, were collected. Time has not yet permitted study of these samples except in a general way, so details regarding their characteristics, distribution, and significance must await publication at a later date. Only a generalized statement can be made at this time.

A relationship between type of sediment and depth of water (fig. 25) is apparent in the lagoon at Kapingamarangi. Of seven principal types of sediment that are recognized, six are restricted to relatively narrow limits in depth, forming a series of bands encircling the deepest parts of the lagoon. The seventh type of sediment is a white silt, apparently formed of comminuted shells, corals, and other debris; it is distributed along the paths of strong bottom currents at depths ranging from a few feet down to at least 200 feet. The other sediments and their general ranges are as follows:

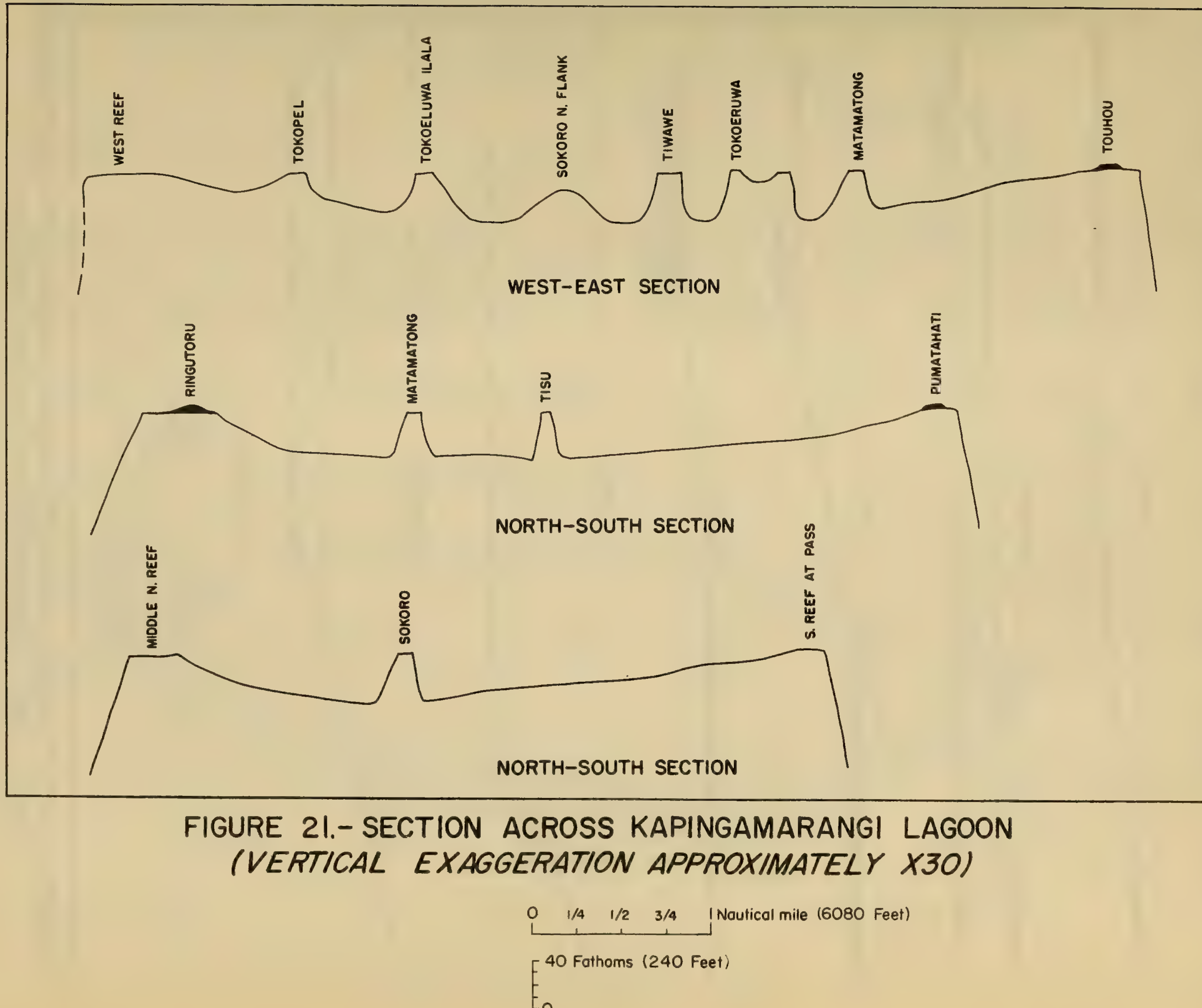


FIGURE 21.- SECTION ACROSS KAPINGAMARANGI LAGOON
(VERTICAL EXAGGERATION APPROXIMATELY X30)

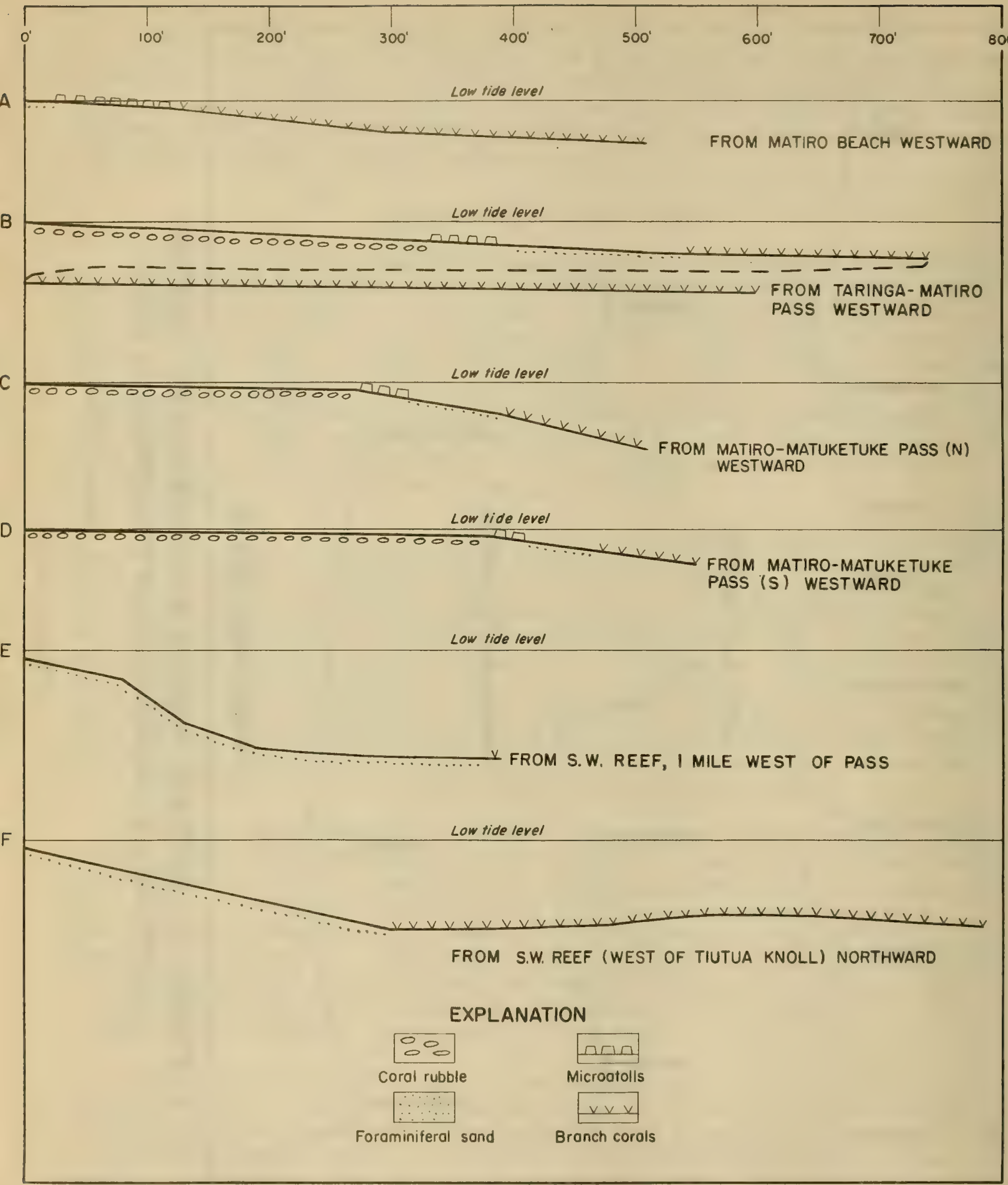


FIGURE 22.- OFF-SHORE PROFILES IN EAST AND SOUTH SECTIONS OF ATOLL AND DISTRIBUTION OF BOTTOM SEDIMENTS

0 50 Feet

Vertical and horizontal scale

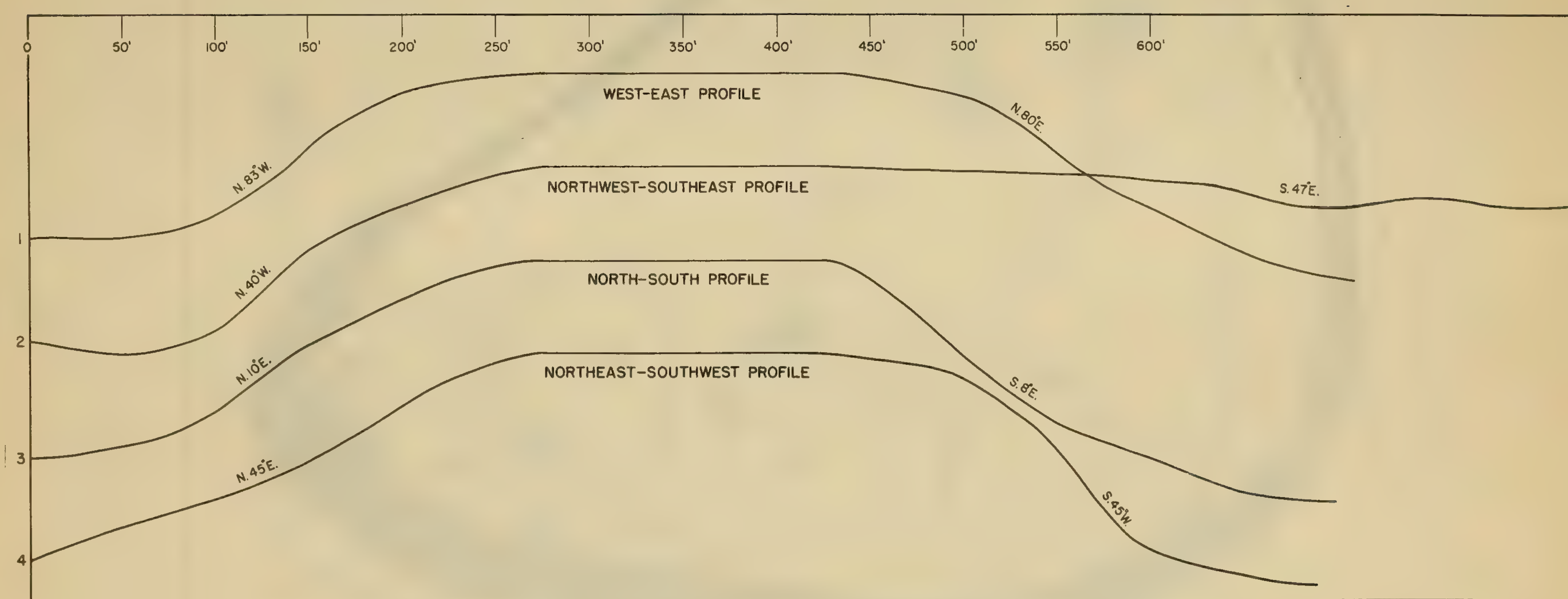


FIGURE 23.-PROFILES OF MANIN PATCH REEF

0 50 100 Feet

Vertical and horizontal scale

FIGURE 24.-ISOBATHIC LINES OF KAPINGAMARANGI ATOLL COMPILED FROM DATA ON U.S. NAVY HYDROGRAPHIC OFFICE CHART 6042.

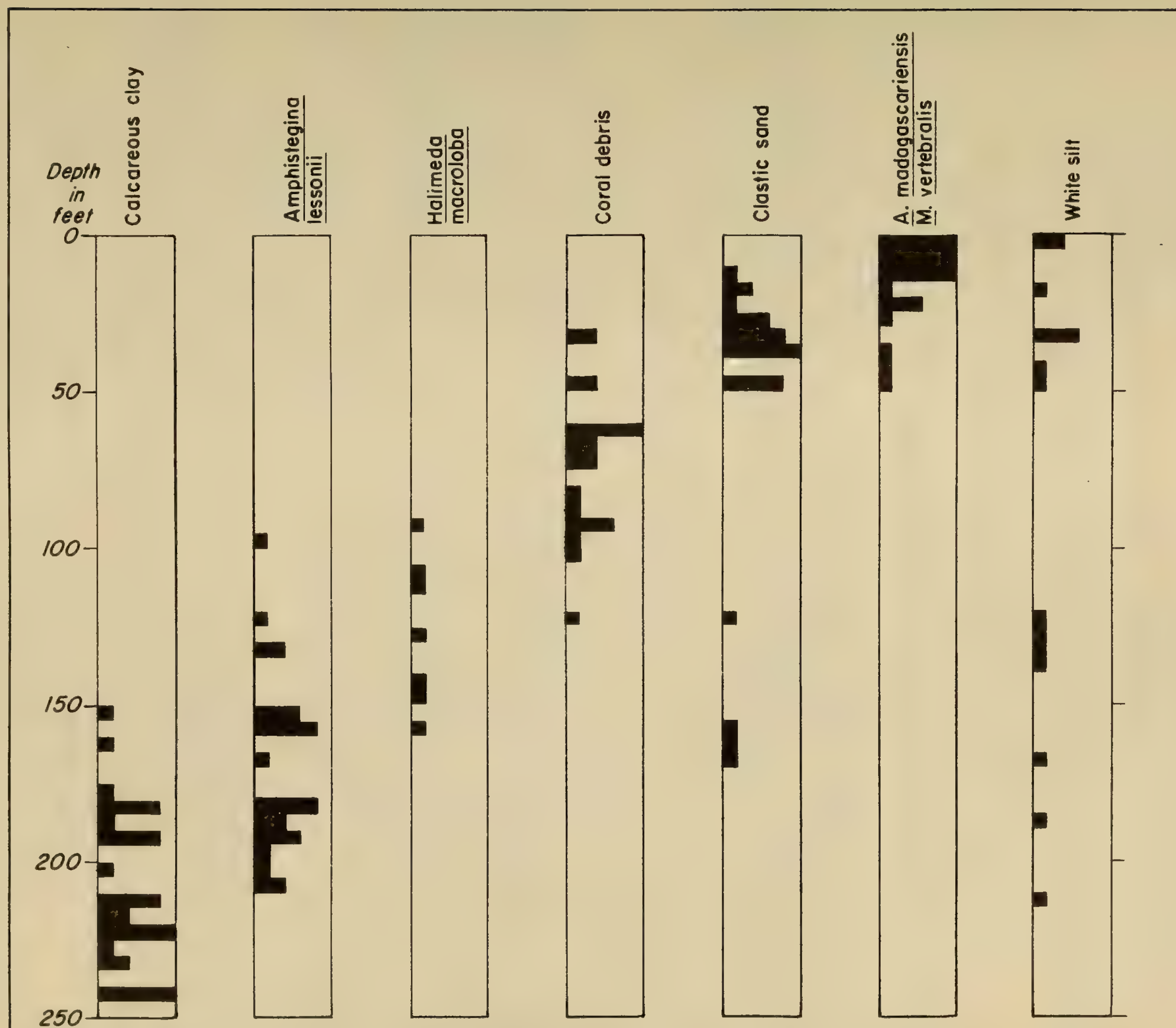


FIGURE 25.-RELATIVE PROPORTIONS OF PRINCIPAL TYPES OF SEDIMENT AT 5-FOOT DEPTH INTERVALS AS DETERMINED BY SAMPLING

1. Sand dominantly of Foraminifera [Amphistegina madagascariensis d'Orbigny, Marginopora vertebralis Blainville, and Elphidium craticulatum (Fichtel and Moll)] -- <50 feet; mostly 0-25 feet.

2. Sand dominantly of clastic shell fragments -- 10-50 feet; mostly 25-50 feet.

3. Coarse debris, largely of dead branch corals, accumulated between and below thickets of living corals -- 30-105 feet.

4. Accumulations of Halimeda macroloba fragments -- 90-160 feet (patchy).

5. Foraminiferal sand (Amphistegina lessonii d'Orbigny) 1/ -- 120-210 feet.

1/ Chief minor faunal elements are Heterostegina suborbicularis d'Orbigny and Operculina ammonoides (Gronovius); others associated are Spiroloculina communis Cushman and Todd, Cibicides lobatulus (Walker and Jacob), and Planorbulinella larvata (Parker and Jones). Identified by M. Ruth Todd.

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6. Calcareous mud (contains aragonite needles and about 10 percent of small Foraminifera) -- 150-240 feet.

Sedimentary belts within the lagoon appear to represent, for the most part, the normal habitats of the various organisms involved, for a large proportion of samples show little of the mixing that would be expected if organisms had been transported by currents into pockets of accumulation. Orange foraminiferal sand of near-shore areas (belt 1) grades outward and downward into white clastic sand of belt 2. Likewise, there is gradation between the Halimeda macroloba sand of belt 4 and the Amphistegina lessonii sand of belt 5. Corals, especially branching types that cover the bottom surface mainly between depths of 30 and 90 feet, form an effective barrier in most parts of the lagoon between the sediments above and below these depths. Fragments of broken coral, many of them large, cover most of the lagoon floor between the living corals.

The calcareous mud which covers most of the lagoon bottom at depths below 34 fathoms (204 feet), but which has been obtained from stations as shallow as 25 fathoms (150 feet), is pale olive green and very plastic and sticky when wet. Mineral analyses made with X-ray diffraction patterns 2/ show that much of this mud is aragonite, but it contains a small proportion

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2/ Analyses by A. J. Gude III, U. S. Geological Survey.

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of calcite. The calcite probably is attributable to the Foraminifera included. These form only a small percentage of the mud but are represented by a rich fauna including many genera and species. In a single sample from a depth of 36 fathoms, Ruth Todd of the U. S. Geological Survey noted 39 species. She reports the following as crude estimates of the percentage of the

total foraminiferal fauna:

	Percent
Cibicides lobatulus (Walker and Jacob)	20
Spiroloculina communis Cushman and Todd..............	20
Virgulina complanata Egger	10
Textularia agglutinans d'Orbigny) T. foliacea Heron-Allen and Earland)	12
Amphistegina madagascariensis d'Orbigny) A. sp. (small, flat worm))	10

"The remaining 28% is composed of about 32 additional species among which one species each of Tretomphalus, Globigerina, Cymbaloporetta, Loxostomum, and Operculina make up the bulk (perhaps as much as 15 or 20% of the whole fauna). The Globigerina is a planktonic form and the Tretomphalus is an attached form with a planktonic stage. Cymbaloporetta and Cibecides may be attached, but are not necessarily always attached. All the others are benthonic forms, so far as known."

The origin of the calcareous mud is not known, and detailed studies of it have not yet been made. Evidence at hand, however, suggests that the mud is not derived primarily from the residue of sediments occurring at higher levels. Although its composition is principally aragonite, it is largely surrounded by a belt of Amphistegina lessonii with a composition of normal calcite. If the aragonite were derived from either coral or shell debris of shallower depths, the difficulty of explaining how it bypassed the surrounding calcite belt is encountered. On the other hand, the presence of some aragonite needles suggests the possibility that it formed as a chemical precipitate.

The overall pattern formed by belts of sedimentation in the lagoon at Kapingamarangi is, of course, much complicated by the many patch reefs that rise above the floor. Each of these has sediments on its top and sides of varieties in keeping with the general depth ranges, except that where slopes are especially steep the lower limits of various sedimentary types extend deeper than otherwise. Further complications in the pattern of sedimentary belts are caused by bottom currents in certain areas. The white silts characteristic of these current zones are especially well developed in and near the main pass on the south, in a broad area bordering the south side of the atoll and within a mile of it, and in narrow zones bordering the western and northern arcs. The east-trending deposits of current-transported silts are prominent in airplane photographs of the southern part of the lagoon.

The problem of why belts of sediment comparable to those in Kapingamarangi lagoon are not recognized in other atolls merits consideration. A likely answer is found in comparative depths: most other lagoons that have

been sampled are shallower than the one at Kapingamarangi. Available descriptions indicate that belts corresponding to those of the relatively shallow waters do occur, i.e., the belts of near-shore foraminiferal sand, of clastic sand, and of coral debris. At Raroia, in the deeper parts (20-25 fathoms), Newell (1954, p. 25) reports a lack of bottom mud but records some accumulations of Halimeda. This distribution parallels closely that for corresponding depths at Kapingamarangi.

GEOLOGY OF THE PATCH REEFS

The evenness of the bowl-shaped basin that contains the lagoon at Kapingamarangi is disrupted in many places by patch reefs that rise as mounds from its sides and floor. Many of these reefs are subcircular in plan, but others are linear, and still others very irregular. They range in size from low knolls or pinnacles a few dozen feet across and 10 or 20 feet high to wide platforms that are 100 feet high or more. Among the largest is Sokoro, whose top is 2,900 feet long and 700 feet wide, and Tokopel, which has an upper surface approximately 1,400 feet by 900 feet (fig. 26).

The total number of patch reefs is not known, but 20 of those listed are more than 500 feet long. Available maps show approximately 75 of all sizes, yet even this number probably is far from the total, for many very small ones and others that do not reach the surface are not included. Counting of patch reefs is further confused because some reefs that appear separate at the surface are connected at shallow depths. Of the approximately 75 indicated on maps, 35 are in waters deeper than 60 feet, including some of the very large ones that rise from the deepest parts of the lagoon. The other 40 patch reefs shown on the maps are mostly small and occur in shoal waters bordering the inner margin of the atoll, especially along its northern and western sides.

Nearly all the patch reefs at Kapingamarangi have flat tops at or slightly above low-tide level, giving to each mound the appearance of a mesa rising up through the lagoon. Only on a few of the submerged reefs do top surfaces appear to be somewhat rounded and irregular. Flat tops are characteristically developed and maintained in most patch reefs because the upward growth of organisms is controlled by tide levels and the surface is continually being bevelled by wave action. The sides are steep, in general, and commonly slope off at angles of 30° to 40°. They have the appearance of being far steeper than this and locally seem to be nearly vertical, but measurements show that most visual estimates are high.

The general shape of Manin knoll in the northeastern part of the lagoon was determined from soundings (table 8). This patch reef probably is typical of most at Kapingamarangi. Profiles (fig. 23) show that its southwest side, in its steepest part, slopes down at about 50° within a vertical distance of 40 to 50 feet, and that the northwest side has a slope of about 40°. These are extremes, and other sides of the reef have more gentle slopes, including the southeastern sector, which extends as a slightly submerged promontory or ridge far out into the lagoon.

Table 8.- Depth (in feet) of lagoon floor surrounding Manin patch reef

Distance (in ft) outward from reef margin	Direction from reference point								
	N40°W	N10°E	N45°E	N80°E	S59°E	S 47°E	S8°E	S 45°W	N83°W
0	2	2	2	2	2	6*	2	2	2
75	24	24	30	18	18	12	54	12	12
125	48	48	60	54	24	24	90	42	42
175	90	84	--	80	30	20	108	102	78
225	102	102	96	102	30	24	126	120	90
275	96	108	114	114	30	24	132	126	90

*Along submarine ridge, 128 feet outward from 2-foot margin.

The distribution and orientation of patch reefs in the lagoon seem to reflect in large measure the trends of currents and waves. A cluster of patch reefs, some of them large, near the ship's pass on the south side of the atoll probably is directly related to the strong currents that maintain good circulation in that area. The many small patch reefs immediately inside the northwestern and western arcs of the atoll apparently developed in response to waves of maximum fetch before the dominant winds. Likewise a general northwestward lineation of many reefs in the lagoon center probably reflects this dominant wave direction. The fact that many of the patch reefs are subcircular rather than elongate is believed to be due to the relative quietness of lagoon waters, allowing nearly equal growth in all directions, as suggested by Cloud (1952a, p. 2140).

All of the patch reefs in deep water, and many of those in shallow, rise from parts of the lagoon bottom that are covered with extensive deposits of foraminiferal sand and calcareous mud. The patch reefs themselves, however, are largely mantled with growing corals. Dense thickets or forests of the yellow, branching Porites andrewsi cover most of the sides, and both microatolls and smaller coral heads, representing numerous species, cover extensive areas on the flat tops, especially along the margins. Typical coral assemblages from three Kapingamarangi patch reefs, identified by J. W. Wells, are listed in table 9. The list served to indicate the principal forms, though others contribute to the reefs also. A comparison of these lists with those of Wells (1954, p. 390-393) for the Marshall Islands shows that all of the genera and all but two of the species of Kapingamarangi occur also in the Marshall Islands.

Table 9.- Some characteristic coral assemblages on Kapingamarangi Atoll, determined by J. W. Wells

	Seaward margin outer reef at Touhou	Lagoon at Matiro Island 50'-1000' out	Patch reef Tokohui	Patch reef Matamatong	Patch reef Thokotaman
Psammocora nierstraszi v.d. Horst			x		
Seriatopora hystrix Dana		x			x
Pocillopora damicornis (Linnaeus)	x	x		x	
danae Verrill				x	x
eydouxi M.E. & H.	x				
Acropora corymbosa (Lamarck)	x				
digitifera (Dana)	x				
formosa (Dana)		x			x
striata Verrill					x
variabilis (Klunzinger)	x				
Astreopora myriophthalma (Lamarck)					x
Montipora composita Crossland				x	
sp. cf. M. marshallensis Wells					x
prolifera Brueggemann		x	x		
verrilli Vaughan	x				
verrucosa (Lamarck)			x		x
Pavona clavus (Dana)	x				
Herpolitha limax (Esper)					x
Goniopora sp. cf. G. traceyi Wells			x		
Porites andrewsi Vaughan		x	x	x	
fragosa Dana		x	x	x	x
lutea M. E. & H.	x			x	
Favia pallida (Dana)			x		x
stelligera (Dana)			x	x	
Favites abdita (E. & S.)		x		x	
Plesiastrea versipora (Lamarck)	x				
Platygyra rustica (Dana)				x	x
sinensis (M. E. & H.)		x			
Merulina ampliata (E. & S.)			x	x	
Cyphastrea microphthalma (Lamarck)		x	x	x	x
Heliopora coerulea (Pallas)			x	x	x
Millepora platyphylla H. & E.			x	x	x
tenera Boschma		x			x

The surfaces of patch reefs, where not covered with living corals, are either occupied by accumulations of clastic and foraminiferal sands or are barren areas of dead coral. The proportion of each is extremely variable from reef to reef. The amount of dead coral area seems to depend, in large measure, on the elevation of the reef top with respect to low-tide level. Tokohui and Timan, for example, are knolls with top surfaces 2 to 3 feet lower than those of most associated patch reefs (fig. 26) and as a result have no extensive areas of barren, dead coral. Their surfaces are largely covered with well-formed corals. Few of the massive types of coral have dead centers or form microatolls, and many of the yellow, branching Porites, which on other knolls grow only on the margins and sides, are well developed even near the centers of these reefs. In contrast, on Sokoro and Tiwawe knolls, both of which stand well above low-tide level, extensive areas of dead, bevelled coral occur in the centers, and microatolls are common along the tops (fig. 26).

Lime sand that accumulates on the upper sides and tops of most patch reefs is similar to that accumulating at corresponding depths off the lagoon beaches and lagoon reef margins of the atoll. This sand consists largely of orange tests of the foraminifer Amphistegina madagascariensis but contains varying amounts of small clastic particles derived chiefly from mollusk shells and corals. Some sand contains moderate amounts of locally derived Halimeda opuntia fragments. From field sketches of 10 representative patch reefs (fig. 26), the characteristic distribution of sand is apparent. In general, sand is concentrated in the centers and on the northeastern margins, below which it commonly covers slopes down to depths of 20 feet or more. The thickness of sand accumulations on most patch reefs does not appear to be great (table 10), and on some, where coral growth is especially luxuriant, sand is confined to small pockets. In contrast, Sokoro, Tokopel, and a few other knolls contain sufficient sand to form bars of appreciable size that rise well above low-tide level.

Table 10.- Thickness (in inches) of sand accumulations on patch reefs

Patch Reef	NE Margin	Center	SW Area
Tisu	6	5	5
Matamatong	11	7	-
Sokoro	-	18	16

Why sand that extends over the rims of the knolls is confined almost entirely to the northeastern slopes is not known. On other sides, where thickets of branching corals are absent, the slopes normally are covered with the debris of dead coral branches instead of sand.

As stated by Ladd and others (1950, p. 421), "the age, origin and internal constitution of the knolls is not known, as no structure of this

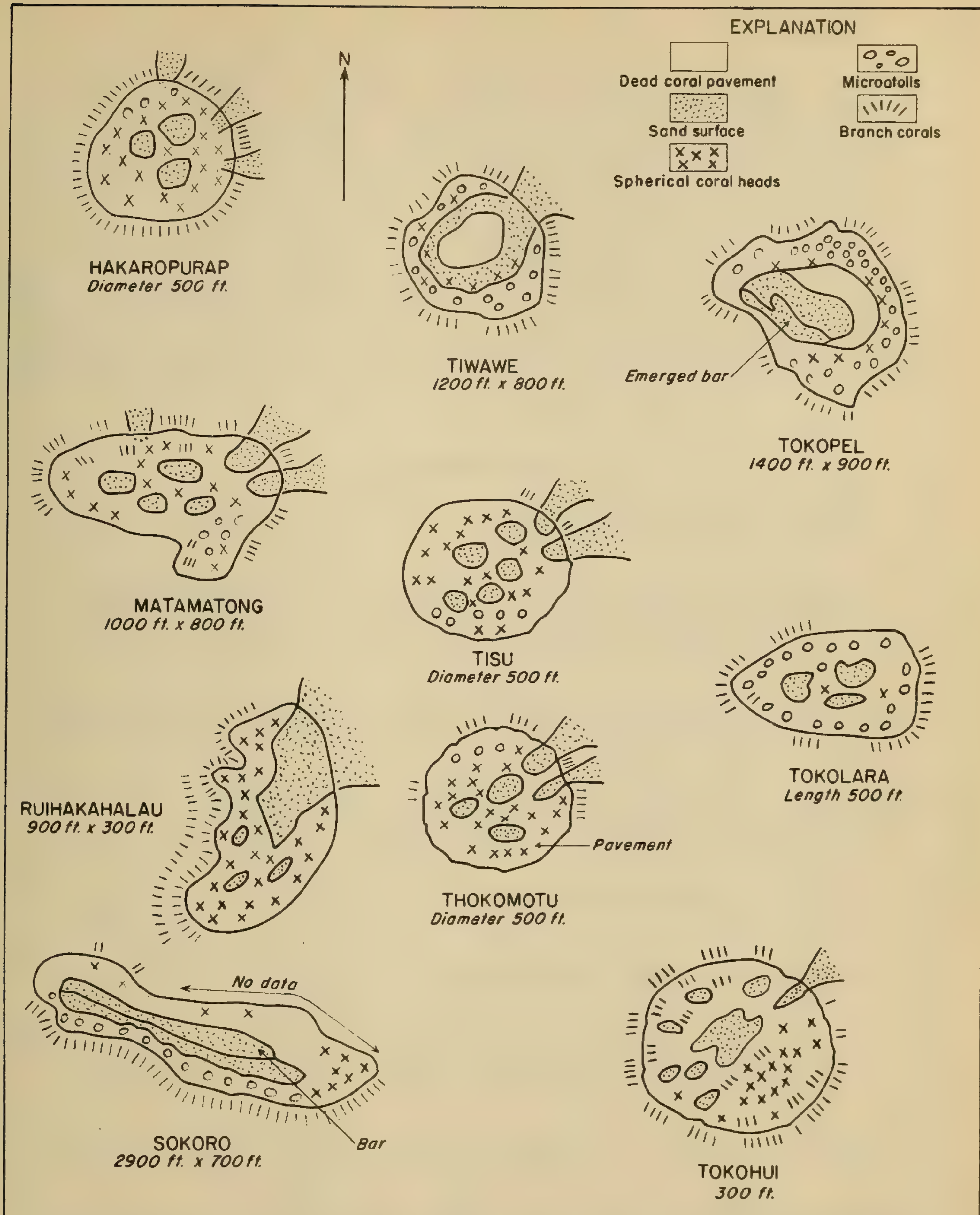

FIGURE 26.-FIELD SKETCHES OF PATCH REEFS SHOWING DISTRIBUTION OF SEDIMENTS AND CORALS

type has ever been drilled." Those writers suggest that the patch reefs may have developed through sporadic coral growth that was initiated during a part of the Pleistocene epoch, when sea level was much lower than now. Such an hypothesis would fit very well the meager knowledge available concerning the shape of the lagoon basin, the extensive bottom sands and muds that are helping to fill it, and the patch reefs that rise to low-tide level within the lagoon. Furthermore, the bevelled surfaces of dead coral, back from the actively growing rims on most of the high knolls, strongly suggest that like the outer reef of the atoll they were higher than at present not far back in history and have been truncated because of a recent drop in sea level. From what may be observed of their simple shape and structure, it seems probable that these patch reefs are similar in all essential respects to the bioherms that have been described from many ancient deposits, especially those of Silurian and Devonian age (Shrock, 1939).

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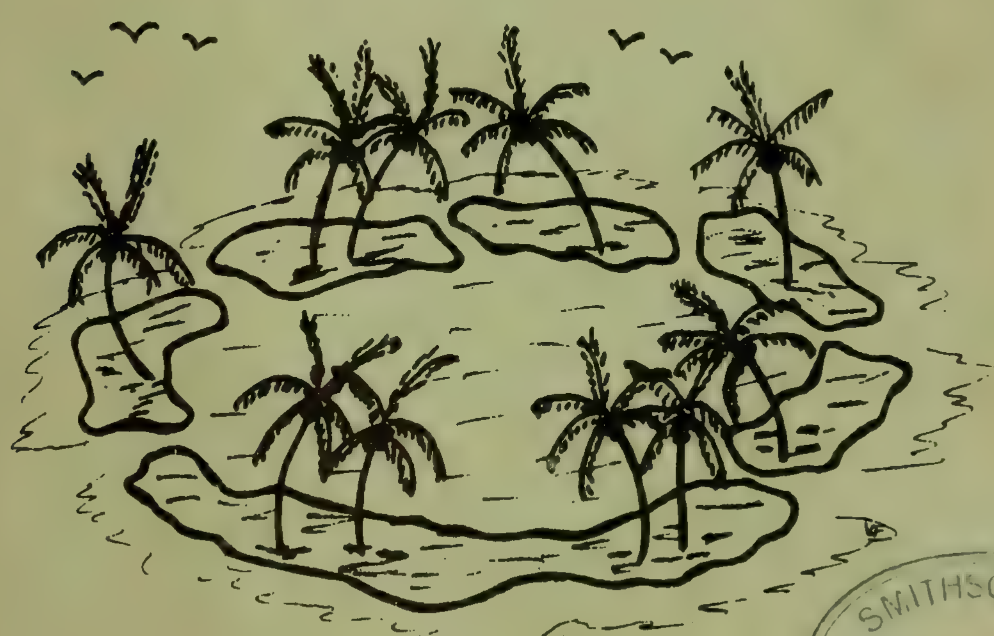

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ACKNOWLEDGMENT

It is a pleasure to commend the far-sighted policy of the Office of Naval Research, with its emphasis on basic research, as a result of which a grant has made possible the continuation of the Coral Atoll Program of the Pacific Science Board.

It is of interest to note, historically, that much of the fundamental information on atolls of the Pacific was gathered by the U. S. Navy's South Pacific Exploring Expedition, over one hundred years ago, under the command of Captain Charles Wilkes. The continuing nature of such scientific interest by the Navy is shown by the support for the Pacific Science Board's research programs, CIMA, SIM, and ICCP, during the past ten years. The Coral Atoll Program is a part of SIM.

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ATOLL RESEARCH BULLETIN

No. 51

Observations on French Frigate Shoals, February 1956

by

Arthur Svihla.

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Observations on French Frigate Shoals, February 1956

by

Arthur Svihla

A visit was made to French Frigate Shoals from February 11 to February 21, 1956, in order to study the life habits, distribution and abundance of the Hawaiian Seal (Monachus schauinslandi). Incidental to the primary purpose of the trip, observations and collections of other animals and plants were made.

I am indebted to the U. S. Coast Guard for transportation to French Frigate Shoals as well as for assistance and cooperation while there.

All collections were made on Tern Island due to inability to visit the other islands in this group. Specimens of plants and terrestrial arthropods which were collected have been deposited in the Bernice P. Bishop Museum, Honolulu, Hawaii.

Tern Island consists largely of the barren landing strip but there is a small area of approximately three acres in extent which still retains some of the original flora. This consists of various grasses (some of which are undoubtedly introduced), the beach morning-glory (Ipomoea pes-caprae) and Scaevola. Around the buildings of the Loran Station three coconut trees and several clumps of Casuarinas have been planted. The trunks of the three coconut trees are about one foot high and seem to be established. The Casuarinas, planted in front of the mess hall are about 15 feet high. They too appear to be growing well.

Under blocks of coral above the beach line as well as under discarded boards were found sow-bugs, crickets, cockroaches, earwigs and spiders. Since soil from Honolulu had been brought to Tern Island, these arthopods might have been introduced in this way. A few house flies were present in the buildings.

The only nesting bird on Tern Island was the Laysan Albatross. Each nest had a single chick about a month old. A few Black-footed Albatross were also present but were not nesting although they were going through the characteristic dancing antics. About 15 Turnstones frequented the vicinity of the mess hall where scraps were thrown to them. Only 1 Sanderling was seen. On several occasions Man-of-War birds were observed flying over the island. Six Fairy Terns flew over the island one day. The most numerous birds were the Sooty Terns which appeared every evening just before or after sunset over the shallow lagoon where they were apparently feeding. Their loud calls could be

heard as soon as they appeared and continued until they disappeared about 3:00 o'clock each morning. I have been informed by one of the men who was stationed there that later in the year these birds nest in enormous numbers on the island, hence the name Tern Island.

The mammals on the island consisted of a fluctuating population of Coast Guard personnel, two house cats (said to be of the same sex) which fed to a certain extent on the birds; two dogs, pets of the men, and the Hawaiian Seal. Four of these mammals were seen on Tern Island. On the return flight to Honolulu a count of seals was made. A total of 32 seals were seen on February 21, 1956, from the following islands of the group:

Shark (didn't fly over)		
Tern	0	(4 day before)
small island in front of Trig	4	
Trig	4	
Skate	10	2 turtles
Whale	7	1 turtle
Round	2	
Mullet	3	
East	1	
on reef in lagoon	1	
	32	

The plane did not fly over Gin, Little Gin or Disappearing Islands.

The previous count of Hawaiian Seals occurring on French Frigate Shoals was 16. This mammal is apparently on the increase here. On some of the islands the seals were seen in pairs, the males could be distinguished by their larger size, heavier forequarters and dark brown color from the smaller, more slender light brown color females. Pairing was apparently occurring here at this time of the year.

Several large sea turtles were also seen from the air.

ATOLL RESEARCH BULLETIN

No. 52

Zonation of corals on Japtan Reef, Eniwetok Atoll

by

Eugene P. Odum and Howard T. Odum

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Zonation of Corals on Japtan Reef, Eniwetok Atoll

by

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Howard T. Odum, Institute of Marine Sciences, Port Aransas, Texas

At the time of the publication of our paper "Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll" (Ecol. Monogr., 25: 291-320. 1955) only tentative identifications of corals, mostly to genus, could be designated since our reference specimens, sent to the National Museum for study, had been returned with only partial identification of some specimens. Since exact identification to species was not necessary in our analysis of total structure and metabolism of the reef, code numbers were used in the text and tables of our paper, pending more complete determinations.

Upon his return from an overseas trip, Dr. John W. Wells of Cornell University, kindly consented to examine our collections during the summer of 1955. He has returned the material to us with his determinations of species. Since the Japtan Reef which we studied is located near the Marine Laboratory on Parry Island and may be frequently visited by workers at the laboratory it seems especially desirable to make available the final identifications. The Japtan reef, being relatively undisturbed, can serve as a "control" for studies of reefs more directly affected by nuclear weapons tests.

The series of corals was collected in a transect across the windward, inter-island reef about one-fourth mile north of Japtan (Muti) Island on Eniwetok Atoll, Marshall Islands. This reef, the physiographic zonation, and the location of sample quadrats have been fully described and pictured in the above mentioned paper. As shown in Figure 1, the reef at the study transect point exhibited 6 distinct zones. No collections could be made from the windward buttress zone. The other 5 zones are designated in Figure 1 and Table 1 as follows: A. Coral-algal ridge (breaker zone). B. Encrusting zone. C. Zone of small heads. D. Zone of large heads. E. Zone of sand and shingle with scattered large heads. The species of corals collected from these zones are tabulated in Table 1. Code numbers correspond to numbers listed in text and tables of the Ecological Monograph paper.

As would be expected, the gradients (from sea to lagoon) in depth of from about 6 inches to 30 feet and more and in current velocity from about 0.5 meter to less than 0.1 meter per second at "average" tide conditions result in sharp changes in species composition along the reef transect. The conditions at low spring tides are probably critical for many species since current velocities are greatly reduced; only a few inches of water may cover the windward zones and the large heads of Zone D may project a foot or more above water for several hours. Porites lobata appeared to tolerate the widest range of conditions as it could be found over most of the reef. Millepora platyphylla was the only species which appeared to exhibit a discontinuous distribution; it was an important species in Zones A and B and again in Zones D and E but not in Zone C. However, the growth forms or "ecotypes" of this species were quite different on the front and back reef; on the former, this coral was largely encrusting while in the deeper water zones the tall, branched finger-like form was prominent.

TABLE 1. Zonation of Corals on Japtan Reef, Eniwetok Atoll

SPECIES	Code Numbers	REEF ZONE A	B	C	D	E
Pocillopora danae (E. and S.)	A-1	X				
Acropora sp. (Encrusting type)	B-1	X	X			
Millepora platyphylla H. and E.	B-2,E-1	X	X		X	X
Favites halicora (Ehrenb.)	B-4		X			
Pocillopora verrucosa (E. and S.)	B-7		X			
Plesiastrea versipora (Lam.)	B-3,B-5,C-2		X	X		
Favia pallida (Dana)	B-8,C-3		X	X		
Porites lobata Dana	B-6		X	X	X	
Favites abdita (E. and S.)	C-4			X		
Cyphastrea chalcidicum (Forsk.)	C-5			X		
Porites lutea M.-E. and H.	C-6			X		
Pocillopora elegans Dana	C-8			X		
Acropora tubicinaria (Dana)	C-9			X		
Acropora conferta (Quelch)	C-7			X	X	
Acropora humilis (Dana)	C-10,D-7			X	X	
Echinopora lamellosa (Esper)	C-11			X	X	
Favia stelligera (Dana)	C-13			X	X	
Acropora corymbosa (Lam.)	D-9				X	
Acropora recumbens (Brook) (?)	D-12				X	
Montipora verrilli Vaughan	D-3				X	
Montipora foveolata (Dana)	D-4				X	
Goniastrea retiformis (Lam.)	D-1				X	
Stylophora mordax Dana	D-8				X	
Lobophytum pauciflorum (Ehr.)	D-10				X	
Millepora murrayi Quelch	E-2					X
Heliopora coerulea (Pallas)	E-3					X
Turbinaria globularis Bernard	E-4					X

As may be seen from Table 1, only three species were found along the breaker zone, which on the Japtan reef was largely covered by algae. On Zone B, the encrusting Acropora and Millepora and small "doughnut-shaped" heads of Porites, Favites, Plesiastrea and Pocillopora were most conspicuous. On Zone C the massive types of Favids and Porites (two species) were characteristic while in Zone D the branching Acroporas were conspicuous. Within the extensive "zone of large heads" there was a noticeable sub-zonation with the Acropora, Porites, Pocillopora and Stylophora in Zone D while Heliopora and the two species of Millepora formed a distinct zone lagoonward which is designated as "E". The scattered large heads on the lagoon edge were largely Turbinaria but we did not use the aqua-lung to investigate the deeper waters. Undoubtedly, there are other species beyond Zone E.

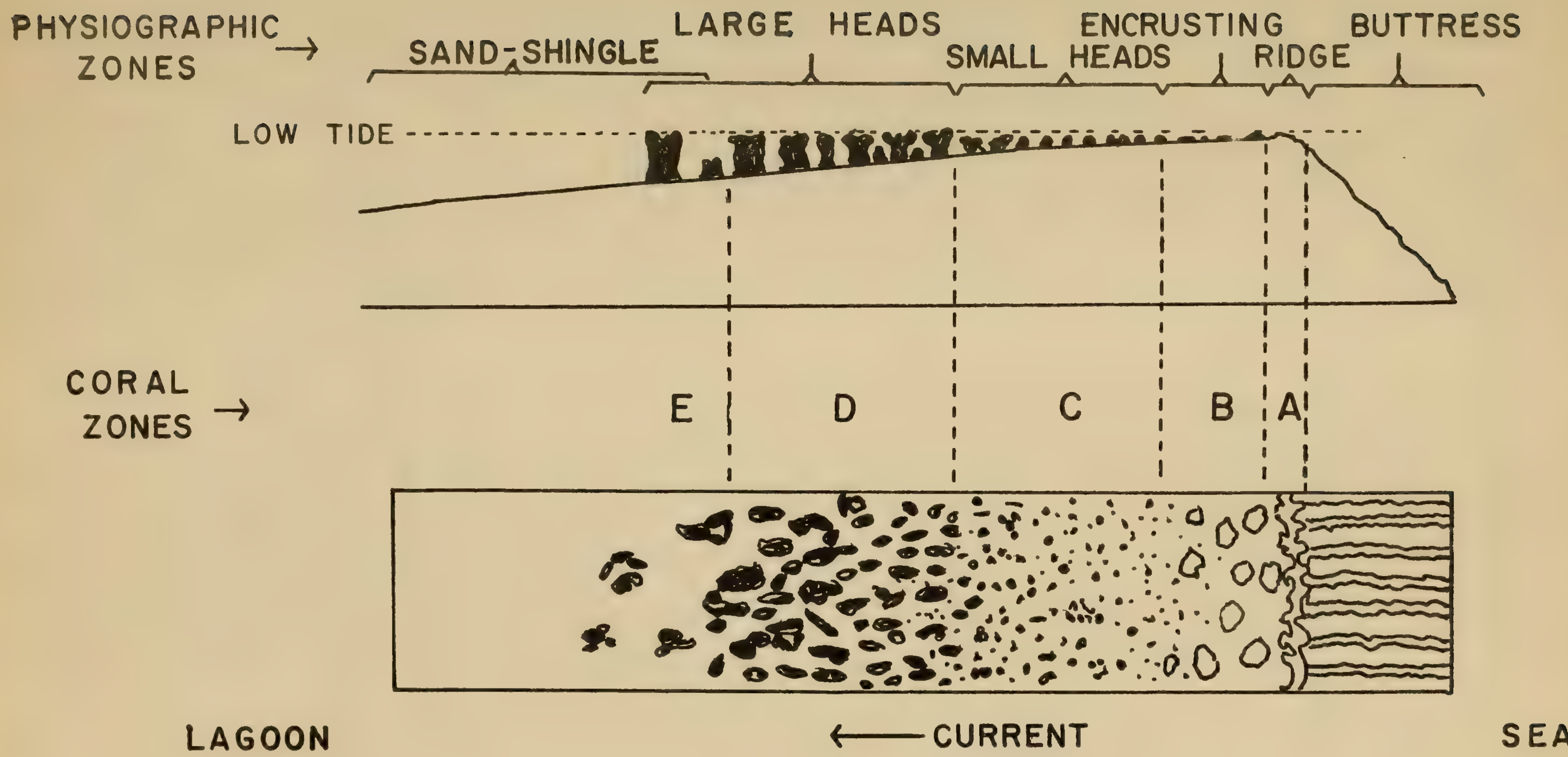
It should be pointed out that species B-3 which was designated as "Leptastrea" in Tables 1, 2, 3, 5 and Figure 7 of our monograph (Odum and Odum, 1955) should be Plesiastrea versipora. This species was of a special interest to us in having multiple bands of skeletal algae. Also of special interest were the two species of Favites (B-4, halicora and C-4 abdita) which had about twice the chlorophyll content per square centimeter of surface as any other species studied.

In addition to the species shown in Table 1, which were the ones actually collected along the study transect, the following additional species were picked up from other parts of the Japtan reef.

Astreopora myriophthalma (Lam.) (M-29)
Platygyra rustica (Dana) (M-19)
Montipora composita Crossland (M-3)
Distichopora irregularis Moseley (M-12)

Finally, the species of Lobophyllia (R-1) which we used to determine polyp and algae biomass (see Table 1, Odum and Odum, 1955) has been determined to be L. corymbosa (Forsk.) by Dr. Wells. We did not find this species on Japtan but collected it on the leeward side of the atoll at Rigili Island. It was used because the large polyp size made possible dissection of components for comparison with the indirect methods used with other species.

Figure 1. Diagram of the Japtan reef transect, side view (upper) and aerial view (lower) showing zonation referred to in text and in table 1.


PHYSIOGRAPHIC ZONES →
SAND-SHINGLE
LARGE HEADS
SMALL HEADS
ENCRUSTING RIDGE
BUTTRESS
LOW TIDE
CORAL ZONES →
E
D
C
B
A
LAGOON
← CURRENT
SEA

ATOLL RESEARCH BULLETIN

No. 53

Slicks on ocean surface downwind from coral reefs

by

F. R. Fosberg

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Slicks on Ocean Surface Downwind from Coral Reefs [1]

by
F. R. Fosberg[2]

During general investigations of certain atolls of the northern Marshall Islands in 1952 (Fosberg, 1955) a phenomenon was noticed that seems worthy of the attention of oceanographers and geologists, although no explanation is offered for it. This is the occurrence of narrow, elongate strips of smooth water, resembling the effect produced by a film of oil on the surface, extending downwind from the coral reefs.

This appearance was first noticed in the lagoon of Ujae Atoll on March 4, 1952, and was observed repeatedly thereafter for more than a week along the windward reef in the southern half of the atoll. A brisk trade wind was blowing, and the surface of the lagoon was covered by a close pattern of ripples, wavelets, and small waves. Perpendicular to the reef and exactly in the direction of the wind were numerous parallel linear streaks, varying from a few centimeters to a meter in width, of perfectly smooth water. These extended several hundred yards downwind. In them there was an abrupt smoothing of the surface disturbance of the water and usually a small accumulation of small bubbles and flecks of foam in a broken line near the center of the streak. The streaks seemed to be of different ages, the younger ones having very clearly defined edges, the older ones becoming broken up or braided in pattern. They tended to become more broken up as the distance from the reef increased, also broader with distance. On a very rough day their boundaries were not clear, and the choppiness was not altogether smoothed out. On a day with only a very gentle breeze the whole streak was not straight but a bit irregular. At about 300 m. from the reef, on the calmer day the streaks became as much as 6 to 8 m. wide. On March 9 similar streaks were seen in the open sea to the leeward of the north end of Ujae Atoll, downwind from Bikenkar and Enelamoj Islets and their connecting reef. These were very well developed, even directly in the lee of the islets. The largest seemed to correspond to large reentrants or surge channels in the reef.

On March 18 similar streaks were seen on Wotho Atoll, in the south part of the lagoon inside the east reef, some opposite the open reef, some inward from the long sand islet on this reef. On March 21 a very good opportunity was afforded to study these streaks inside the north reef of Wotho, west of Eneobnak Islet. Here are several channels crossing the reef, broad toward the seaward side of the reef, narrowing toward the western projection of the islet and sweeping westward around this projection before entering the lagoon. On the reef they run between flats of reef conglomerate and rubble tracts lying on the reef flat. A fairly strong current was flowing inward from the sea to the lagoon. In these channels the slicks described above were

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1/ Publication authorized by the Director, U. S. Geological Survey.

2/ Botanist, U. S. Geological Survey.

very prominent, following the direction of the wind rather than that of the current, though these directions were only a few degrees apart. Although previous observations were all made from small boats, here it was possible to examine the streaks much more closely while wading in waist-deep water. Careful examination revealed no iridescence, whatever. The boundaries were extremely sharp. There was a suggestion of a difference in the feel of the water in the streaks from that nearby, but nothing very tangible or describable. There was no difference in taste or flavor. An attempt was made to follow the streaks to their sources, which seemed to be in the rubble tracts to windward, but this was unsuccessful, as the streaks gradually became invisible in the very quiet water as the rubble tract was approached. There was nothing in the rubble tract to suggest an origin for this phenomenon. There seemed little chance that oily material from the open sea could be responsible for the phenomenon here, though such an origin could not be excluded.

On March 24 similar streaks were seen in the open sea to the leeward of the south half of Bikar Atoll. They were quite numerous, but where the observations were made, from the deck of the ship a quarter to half a mile from the reef, they were rather braided and broken up, but some were still fairly strong. On March 25, at Pokak Atoll, the northernmost of the Marshalls, such slicks were conspicuous at sea on the leeward side of the leeward reef, especially near the single channel through the reef. They extended for several miles downwind, becoming very diffuse at that distance. Here they were only observed from the deck of the ship.

All of the above observations were made in the spring, in a season of strong trade winds. Another visit was made to Pokak and Bikar in July and August, in much calmer weather. A special attempt was made to observe this phenomenon further, but then it was much more difficult to see the slicks clearly. What appeared to be the same type of streaks were seen several times; however only once, on August 9, were unequivocal observations made. This was in the lagoon of Bikar Atoll where a few not especially clear or sharp streaks were seen inside the windward reef between Almeni and Jaboero Islets. There seems no doubt that the phenomenon occurs during these calmer months, but because of the weakness of surface disturbance there is so little contrast that the slicks do not show up very well.

The above observations form all of the factual data to be considered. There seems little doubt that the phenomenon is a real one that is reasonably constantly associated with coral reefs, at least in the northern Marshalls area. That it was not seen near any of the eight other atolls visited earlier in the same expedition is probably simply the result of attention not having been called to it previously. The expedition did not primarily concern itself with the ocean but with reefs and islets. After the slicks were first noticed they could usually be found in any similar situation to the leeward of reefs in brisk weather.

The appearance of these slicks strongly suggests the presence of minute quantities, perhaps monomolecular films, of some substance that strongly alters the surface tension of the sea water. The smoothing out of ripples is abrupt, localized, and of considerable duration, not shifting and inconstant as would be expected of phenomena due solely to wind interacting with the surface of the water (see Langmuir, 1938). The dependence of slick formation on the presence of films of organic matter on the surface of the water has been stressed by most authors who have discussed such phenomena in recent years (Dietz and LaFond, 1950; Ewing, 1950a, 1950b). The combined influence of organic films and effects of strong winds, as suggested by Ewing (1950a, b) should not be disregarded as a possibility, though the "braided" appearance of old slicks contrasted with the sharpness of new ones parallel and simultaneous with them is hard to reconcile with any wind-induced phenomenon. The nature of the pattern observed in the Marshall Islands does not at all resemble the pattern of light and dark bands in the Gulf of Panama discussed by Woodcock and Wyman (1947) as shown in their photographs in plates 6 to 8.

The arrangement of the streaks, at irregular intervals running down wind from the reef, suggests the possibility of frequent emission of minute quantities of some oily material from the reef or from some organism connected with the reef. F. S. MacNeil (in conversation at the time) reported seeing small emissions of bubbles coming out of reefs in places. The possibility has not been overlooked that these slicks may be due to waste oil (from steamships) that may be washed over the reef from the windward side. This, however, seems precluded by the observation of the same phenomenon to leeward of long islets where no water could possibly come over from the windward side. These islands are, also, far from lanes of heavy ocean traffic at the present time. There seems little doubt that these streaks originate on the reef itself.

These facts are placed on record in the hope that either a convincing solution to the problem of the origin of the slicks may occur to someone else or that further investigation may be deemed worth while.

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ATOLL RESEARCH BULLETIN

No. 54

Field notes on atolls visited in the Marshalls, 1956

by

Herold J. Wiens

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FIELD NOTES ON ATOLLS VISITED IN THE MARSHALLS, 1956

by

Herold J. Wiens

Since the spring of 1955 I have been engaged in a study for the Pacific Science Board of the National Academy of Sciences-National Research Council in which I am attempting to analyze, synthesize and generalize to the extent of my capacity certain scholarly data and other published information about coral atolls and reef islands in the tropical Pacific. These data pertain to the physical environment and general ecology of such atolls and islands, to man's situation and role in them, and to the inter-relationships between man and his physical and biological environment on them. In the summer of 1954 I was the geographer on the Pacific Science Board expedition to Kapingamarangi in the Eastern Carolines and briefly visited 5 other atolls and an uninhabited reef island in this region. With the goal of gaining better insight and perspective on the aspects of coral atolls and reef islands in different precipitation zones, I pursued further field studies in the summer of 1956, visiting briefly or for longer periods eleven different atolls and two single reef islands in the Marshalls. Although pre-planning of itineraries proved to be rather futile, it turned out that I was able to visit representative atolls and islands in the dry northern, intermediate humid and wet southern parts of both the eastern and the western chains of the Marshalls.

The notes presented here generally were typed up with little change from field notes written while on the atolls described or immediately after departure from them. They should be viewed only as field notes, therefore, and not as systematic studies of any sort. All types of information striking my attention were jotted down. Most were from direct observations; others were derived from informants. The amount of time spent upon any atoll differed from that spent on others, and I had no control over my transportation schedules. Traveling was done by small 50-70 ft. schooners for the most part, although two or three trips were made by air. On some atolls there was time only for one to several hours of ground examination during daylight. On others, several days were available, although owing to heavy continuous rains on such atolls as Arno and Ebon, not all the time in such longer stays could be used to advantage. The distribution of the islets along scores of miles of reefs, the changing state of the tide interrupting travel between islets, the lack of local transportation, and the fact that visiting schooners stop only at one or two of the scattered bits of land combined with the briefness of the stops in limiting my observations. These limitations account for the fragmentary character of these observations and for their unequal amount and quality.

The reader is begged indulgence for these deficiencies. The notes are offered in spite of them if for nothing else than that some of these atolls are seldom visited, and little is known of them. I gratefully acknowledge the aid and cooperation of the United States Naval authorities on Kwajelein and of the District Administration of the Trust Territory at Majuro and

Ebeje (Kwajelein) under District Administrator Maynard Neas. I wish to express my thanks to the Marshallese on all the atolls and islands who showed me their kindness and hospitality in numerous ways, especially to Capelle, Melander and Felix DeBrum and to Maas Hone of Likiep Atoll; to Maida Kabua of Ailinglaplap; and to Nashon, magistrate at Ebon, and to his father's family. For kindnesses shown in my marine voyaging, I want to thank Captain Rudolph Moeller of the Administration schooner Frela, Walter Milne of the trading schooner Raete, and Father Donohue of the Catholic Mission schooner St. Joseph. I am indebted to Clarence and Sachi Takeuchi and Milton Sidaris of the District Administration for their kind hospitality at Majuro and Jaluit respectively, and to District Anthropologist Jack Tobin for his cooperation and information. Most of all, I wish to express my appreciation for the exceptionally cordial hospitality and kindnesses shown me by Richard Umhoefer, District Administration Representative at Ebeje, and by Mrs. Umhoefer.

Ailinglaplap Atoll

Woja Islet was examined during a brief stop of an hour or so. The headman of the village is Melan; an interpreter for me was Menajo who conducted me on a walk through most of the "village" which has some 300 people.

A relatively luxuriant vegetation grows on this islet. Two large trees (*Hernandia sonora*) were seen on lagoon shore. Two types of taro-like plants grow here: one *wot* (*Alocasia macrorrhiza*) is reported as not being good to eat because of microscopic needle-like crystals in it; however, many plants of these were seen growing wild underneath the breadfruit and coconut trees; the other is called *yaroj* or *iara* (*Cyrtosperma chamissonis*), and is eaten. Breadfruit grown here are of three types called *botagetok*, *mejwan*, and *pukrol*. *Kengi* or *gengi* (*Pemphis acidula*) occurs both on ocean and lagoon side and is used for making charcoal among other uses. A decorative plant or weed is *deroj* or *diros* (*Pseuderanthemum carruthersii*) with purplish green leaves. A creeper, probably a morning glory vine and a plant identified as *ninkijei* were observed. *Asplenium nidus* fern occurs widely. On the windward lagoon shore a rather marked development of stratified beachrock occurs with a strong dip lagoonward, the layers well eroded and clearly defined.

The longest islet on Ailinglaplap has two names, for the two settlements found at the respective ends. The eastern end is called Airik and the western end Buoj, with an estimated 500 and 300 people respectively, according to the medical aide, Maida Kabua. A channel lies between Buoj and the next islet, Bikajla, and a sheltered anchorage is found on one side of the channel adjacent to Buoj.

The long islet is about 7 miles long in a large bow shape; it becomes very narrow (about 100 feet wide) in the middle section and is widest at Airik the larger of the two settlements and the location of a newly built Protestant church of rather elaborate construction and colorful decoration. The islet is noted for the development of a tidal basin with mangrove swamps (not true swamps) in which three types of mangrove are found, *bulabol*

(Sonneratia caseolaris), jong (Bruguiera conjugata), and eoeak (Rhizophora mucronata); the latter has an oblong shaped leaf; photos of all three types were taken. One Hernandia sonora seen was one foot in diameter. Merlap (Canavalia microcarpa) of a light purple color was observed. The islet as a whole impressed one with the abundance of pandanus and tall breadfruit trees. At the tip near Airik the coconut trees are in sandy soil and tend to have a chlorotic color and are low. However, a well with water tasting fresh occurs only 30 feet from the lagoon shore, with surface water (at the tidal stage observed) of four feet below the surface of the ground. Seagrape bushes and a variety of croton bushes are common decorative shrubs along the sides of the road traversing the islet. Other common trees are Hibiscus, Plumeria, Calophyllum and Barringtonia.

Residences observed on Buoj and Airik appear better than in most Marshallese settlements, about on a par with those of Likiep and Ebon. The magistrate here is Jorninea; Luta is headman of Buoj and Leiran is headman of Airik. Both Marmoru and Maida speak English well. Albert, a Gilbertese married to a local Marshallese Catholic is a Protestant who is building a store to compete with Mieco. He speaks excellent English. A neat, clean medical clinic with two rooms stands a couple of houses from the home of Maida Kabua who is a descendant of the Kabua kings whose graves are situated across the road from Maida's house in Buoj. Maida said that serious diseases or accidents rarely occur; skin infections, eye infection, and colds are the commoner afflictions. The new Protestant Church almost completed and subsequently dedicated in early August 1956 was designed by a Marshallese carpenter trained in his profession by the Japanese during their period of occupation. He has displayed a good deal of imagination in decoration, if his color schemes are a bit garish in their primary colors.

Bikajla Islet across from Buoj shows an extraordinary development of coral boulders lying loosely, and apparently permeable to salt water for about 250 feet inland from the ocean-side. In the outer parts dense growths of Morinda citrifolia and Guettarda lie in almost rainforest gloom, with liana-like vines of a Wedelia-type weed falling from their crowns and hanging leafless in the perpetual shadows. Farther inland Bruguiera conjugata provides dense shade, intermingled with some Pandanus, its gnarled, humped-up roots covered with a hairy green coat of algae or lichen. The land forms a low trough here. Asplenium nidus and Nephrolepis acuta grow on the trunks and old stumps of coconut and other trees. Throughout the seaward 200 feet or so pandanus jungle predominates. Few coconut trees occur until, toward the interior, a rise on the lagoon-side of the trough and fresh-water-holding soil have allowed a dense growth of young coconut sprouts among older trees. The islet looks as if no man had disturbed things for decades.

A brief stop was made at Bikar Islet on the north end of the atoll. Here only one or two residences were inhabited. The south end of Bikar appeared to be a relatively new addition of sand with numerous pioneer plants. Strong wave erosion on the lagoon shore has almost destroyed the rock-lined road built during Japanese or German times, having undercut 10-20 feet of the lagoon shore land. Orange colored algae cover the reef rock extending into the lagoon side of the inter-islet channel on the south side of the islet.

Ailuk Atoll

Ailuk Islet is the main residential islet, but is rather small, not more than 1500 feet long nor any wider. No unusual topographic features were observed. There are no very large islets on Ailuk Atoll.

Breadfruit trees were numerous and mostly 40 feet tall or lower, although several were up to 60 feet tall with trunks more than 3 feet in diameter, indicating that the storm of 1951 probably had not been so damaging as it was at Utirik. Generally the vegetation under the coconut trees was similar to that at Utirik and Mejit, with arrowroot very prevalent everywhere. Many taro pits were seen in the interior, but in several only small parts were planted to taro. Most of the pits had been abandoned to weeds.

On the north channel side of the islet *Pemphis* is the main bush, while *Scaevola* becomes more common on the ocean side beaches. Numerous bushes of *ulej* (*Clerodendrum inerme*) grew in the vicinity of the taro pits.

Numerous large sailing outriggers sailed in to the waters of the lagoon (village) from the relatively large islet at the opposite end of the lagoon.

On the oceanside someone had written just before sundown in the wet sand a long line of words carefully inscribed in Marshallese followed by the English sentence: "Please remember me always, Nathan," apparently intending the inscription to be washed away by the next high tide and so having the message conveyed to the heart of the loved one.

Arno Atoll

Ine Islet has an unusually high sand ridge on the lagoon side and in the northern part of Ine village. A fine wide sand beach of moderate firmness for walking is found most of the length of Ine on the lagoon side. The seaward side of Ine has a high level coral boulder rampart over 100 feet wide sloping gently toward the low center of the islet which is well cleared of undergrowth. Some taro pits are in use for taro, but others have been abandoned. Much breadfruit is produced from the numerous trees, and there appears to be an abundance of banana and pandanus trees. The village houses are for the most part rather poorly constructed and maintained. The village school is in a dilapidated condition which is inexcusable; walls rotted away and tin roof full of large holes; the floor wet with water and littered with debris. A dedication plaque surmounted with an Air Force Wings insignia indicates the building was constructed or completed December 3, 1944, when the C.O. of the area was Lt. Col. C. V. Burnett, stationed at Majuro.

Kojboy (Kij-Bwe) Islet near one of the passes provides a sheltered anchorage for ships wishing to anchor just inside the pass. It has a fine sand beach facing the lagoon, with a coarse boulder and cobbled beach on the windward side above a solid rock bench rising two feet above the reef flat. This bench has been well smoothed by the grinding of sand and gravel worked back and forth by waves. Inward from the beach coarse coral boulders loosely

piled and blackened by algae reach 30-100 feet toward the middle of the islet. On this, Scaevola is most prevalent, followed by Pandanus and Guettarda. On the end of the islet facing the pass, the coral boulders reach inward to greater depth in a series of ramparts.

This type of islet structure is typical of many observed throughout the Marshalls as well as at Kapingamarangi in the Carolines. It leads me to believe that the coarse coral blocks on the seaward side, up to one or two feet in diameter and loosely piled, must have been deposited at one time in a single major storm. The modern beach fronting this layer of blocks at Kojboy, for instance comprises mostly smaller gravel, well rounded and polished and piled in a ridge or sometimes in two or more ridges above the solid rock bench and forming the beach proper. At other islets where wave action has eaten inward upon the islet, such coarse coral boulders, little worn and rounded by wave action, have been observed to be underlain by well worn and rounded gravels and finer materials.

Along the end of Kojboy Islet facing the pass, the swift current and tidal pounding have left no sand accumulation as often is the case at points facing shallow inter-islet channels which are dry at low tide. The beach accumulation forming the lagoonward-turning point of the islet here comprises coarse cobbles and gravels overgrown with a scattered growth of Scaevola.

In the interior of Kojboy, the ground under the coconut palms has been kept cleared except for low shrubs, ferns and grasses. One or two families have residence houses here, but the taro pit in the center is not used for taro, but has been abandoned to weed growth.

Like the other islets observed, Arno Islet has a similar coarse cobble beach on the seaward side, with a fine sandy beach on the lagoon side. On the eastern end where the island becomes attenuated and connects with a very narrow (50-80 feet wide) islet east of it, the connection is a sand ridge apparently broken at times when storm waves or spring high tides bring water sweeping across it. Small boats can land readily on the south or seaward side when winds are not strong from the southeast.

Arno Islet has comparatively great width for atoll land areas, and the interior of the wide portion has become overgrown. Weed tree species or coconut jungles are virtually impenetrable in small sections. Numerous former taro pits in the central portion have been abandoned to become pandanus swamps. Domestic pigs have been allowed to run wild and find many coverts and thickets in which to hide. Large numbers of breadfruit trees grow on the island, together with plentiful pandanus and banana trees. Residences are widely separated for the most part.

Ebon Atoll

Ebon Islet is the largest and widest islet on the reef and compares with Arno Islet on Arno Atoll in width but is much longer; the northwestern five miles or so is mostly narrow, 50-150 feet in the middle part and widening to about 500 feet in the northeastern tip. The seaward beach is a very firm,

sand to gravelly sand beach for much of its length, possibly with hard rock underlying it. Except for the village area in the wide part of the islet, the lagoon side northeastward is not sandy but has a rocky to gravelly beach with extensive rock flats exposed at low tide. The reef flat on the ocean side is rather smooth with few loose rocks and boulders. Erosional remnants of former islet bedrock are revealed in the northeast central sector of the islet by a series of jaggedly eroded rock platforms 10 to 20 feet wide and up to 30-40 feet long. These are spaced in a line of half a mile or more flanking the lagoon rock flat about 100-400 feet off the present lagoon shore and above tide water. They lead me to believe that once the islet here was up to 500 feet wide instead of the present 100-feet. The erosion that has taken place has been largely on the lagoon side where the present hard rock flat now stands. In the extreme northeast part of the lagoon, an amazingly flat limestone reef bare at low water is almost smooth enough for roller skating. The jagged remnants above the reef flat support a good growth of Pemphis acidula, with roots anchored in erosional pockets containing some sand and holding fresh water after rains. These remnants rise $4\frac{1}{2}$ feet above the surface of the reef flat. These erosional remnants are similar to eroded bedrock in other areas, in the sharp and jagged character of the surface, which type of surface appears to occur most often where rain water dissolution rather than wave action is the disintegrating factor involved.

A pace measurement of Ebon Islet at the new church, in a line running from ocean side to lagoon side, showed a width of 600 feet. The wide part must be four or five times this width. A 50-60 foot strip bordering the ocean side stands as a relatively high beach rampart from which the land slopes inward toward a central trough which in places reaches within a foot of the fresh-water-lens surface, as revealed in dug wells and in taro pits. Roads 6 feet wide border the residential and wide part of the islet, 50 feet from the ocean beach and 150 feet from the lagoon beach.

Vegetationally, Ebon Islet is one of the richest seen in the Marshalls. Here are the most numerous lime, banana, breadfruit, and papaya trees as well as numerous pandanus trees. Most of the islet is kept well cleared of undergrowth, so that coconuts may be gathered easily. In the central parts of the wide section, however, vegetation has been left to grow unchecked, with a dense cover of all types of characteristic atoll trees in almost jungle-like masses amidst which are nearly concealed taro pits which are poorly maintained, overcrowded with ferns and grasses and unlike the neatly weeded taro beds of Mokil, Pingelap and Kapingamarangi in the Eastern Carolines. This greater carelessness may be due to the fact that men in the Marshalls have the job of farming whereas in the other areas women do the taro-pit work and own the taro patches; at least this is the case in Kapingamarangi. Morinda, Hibiscus and even Guettarda crowd the central portions of the islet together with Pandanus and occasional breadfruit trees. In this central overgrown section, however, coconut trees are dead and decapitated or old and in poor condition and are few and scattered. I was informed that coconut trees did not grow well here.

Possibly this condition may be related to the existence here of too high a concentration of phosphate; for the Japanese dug and exported a phosphate rock from here, some piles of which remain heaped-up next to the lagoonside road from the war period. The neglect of this interior area also may be related to the richness of food production on the islet and the relative sparseness of population for so large an area. Certainly the houses and yards show an evidence of care and prosperity not seen elsewhere in the Marshalls except at Ailinglaplap, or possibly at Likiep.

On the northeast part of the islet where the width reaches about 500 feet, coconut trees are tall and crowded, but the undergrowth is kept down to low weeds and ferns of which there are plenty. The weeds here are Vigna marina and Wedelia biflora, with some Guettarda and Pandanus here and there. The ground often is almost bare of weeds where a cobbly surface prevails. Even in some of the narrower parts, scarcely 50-60 feet wide, some breadfruit trees grow, possibly because the alignment of the islet here with the wind direction reduces the ingress of salt spray.

The amazing ability of coconut trees to gain a footing in the most barren situations is revealed by the five adult palms, plus a small pandanus and one young coconut tree growing on Nakor Islet separated by a channel from the northeastern end of Ebon Islet. Nakor comprises a small sand patch 10 feet by 20 feet on top of bare rock washed by salt water at high tide. Apparently the sand cover of 1-2 feet depth plus pockets holding fresh water in the rock after rainfall supplies the moisture needed by the plants.

On the southwest end of Ebon Islet just beyond the last residence house a tongue of sand stretches in an arch toward the lagoon. On this, pioneer seedlings include Calophyllum, Messerschmidia, Scaevola, Pandanus, coconut, Wedelia, Cassytha, and several grasses.

Breadfruit trees on Ebon for the most part are of a low variety and not exceeding about 60 feet height. A specimen of kirak or kurak (Inocarpus fagiferus?) observed was about 60 feet tall and had somewhat yellowed leaves.

Southwest of Ebon Islet are two islets close together connected by a ridge of sand where spring high tide probably washes through. The one nearest Ebon Islet is Enearmi, meaning "island of people", about 600 feet wide and somewhat longer. The other islet is narrower and about the same length. About half of the former on the ocean side which is lee to the wind is covered with loose coral blocks providing an unstable foothold. Apparently the ground underneath comprises materials holding a fresh water lens however, since the area is richly productive both of coconuts and of tall large breadfruit trees with trunks up to five feet diameter. Black humus was observed in parts where the surface was cleared of coral blocks. The ground is heaped everywhere with piles of moulding coconut husks and fallen fronds and is poorly cleared. The leeward half facing the pass in to the atoll is high with boulders, and slopes to a low elevation toward the center. The coral blocks give the impression of having been pushed inland, possibly during a single typhoon, and their rough shapes contrast with the smoother sand and wave washed cobbles and

gravels forming the modern beach. Everywhere Asplenium nidus and Nephrolepis grow upon the ground, stumps and coconut trees. Morinda citrifolia is a common understory tree. A small plant observed was called rebijreka (probably Peperomia in this habitat) meaning "to hold to the rock."

The reef flat oceanward has a bumpy looking surface with imbedded clams about three inches in diameter. Apparently owing to rather strong winds and waves during the previous night, large quantities of branching antler corals from the lagoon had been washed up onto the shallow parts of the reef flat in the inter-islet channels southwest of Ebon Islet and adjacent to the ship pass, there to die and rot. Tide pools with only an inch or two of water at low tide contained several types of corals, including one with light blue tips and clustered branch effect, a massive dark-blue, flat, fingered type, and the massive brain coral and "micro-atolls" with all but the outer ring dead, usually of an orange purplish color in the live fringe.

Culturally speaking religion plays an important part here as elsewhere in the Marshalls, most of the population of about 800 being Protestant. There are two Protestant churches, one a wooden structure with tin roof and the other, a mile down the other end of the settlement to the southwest, a thatched roof building. Adjacent to the latter is a large new concrete church being built (has been under construction for three years, but lack of concrete blocks stalled completion) which is to be finished for the centennial in 1957 of the entry of Christianity to Ebon and the Marshalls. In the religious homes Protestant families have prayers and hymns at evening and before breakfast, while on Sunday church services in the morning from 10-12 (the first hour for general church, the second for Sunday School) and Christian Endeavor in the afternoon fill the time. No work is done. Special services also are held at the first of the month, and there are prayer meetings during the week, usually on Wednesday.

The two houses of the magistrate's family and relatives each had a phonograph with records of religious, hillbilly, Japanese and cowboy songs. The magistrate informed me that there were four or five battery-operated radio receivers on the Islet which got news and music from Majuro and Kwajelein broadcasting stations. He was informed of the arrival of our schooner before it was sighted. A pool "hall" for billiards is the most popular resort of the atoll sports, and this is a common feature on other Marshall atolls as well, some having more than one billiard table. The job of children here is to pick up all leaves of breadfruit and other trees in the residential yard every morning and remove them or pile them up away from the yard, as observed at Kapingamarangi: in contrast to the latter atoll where women do all the cooking, and associated activities, I saw a man grating coconuts, sitting in a cookhouse with the women. Raw fish here as elsewhere in the Marshalls is often eaten as soon as caught, and the internal organs appear to be especially prized. Children catching small fish bite open the stomachs and eat the flesh, prying into the innards with fingers and licking them as an American child would clean a cake-mixing bowl.

A curious decorative emblem observed set in embossed concrete over the new church windows is a star inside a crescent, but with no known relation to a Moslem origin.

Unfortunately, less care is exercised toward the public school building and desks, chairs and books. The latter were scattered about hither and yon, amid other debris, and a few books lay open on the damp floor of concrete including three copies of a book entitled: "The Wonderful World of Science" about third grade level, and three copies of a song book entitled "New Music Horizons."

The old pastor here is by name Tokeak, two of the deacons are Jokiarik and Langwor. The latter is the adopted father of Nashon the 21 year-old magistrate who speaks a fair English and who entertained me hospitably for four days at his father's house.

Walter Milne, representing his brother, James Milne, who owns the schooner Raete on which I traveled, traveled himself with the schooner, but hired a Marshallese for captain. Walter who had been put up by Ebon people when his house was demolished by bombing or shelling during World War II, paid off his longstanding obligations socially by throwing a big party for his wartime hosts on the schooner, sailing around in the lagoon and feeding his hosts and friends there; this being the express purpose of the trip to Ebon. He also brought them numerous presents.

On the schooner I observed several pillows used by the Marshallese with pillow cases embroidered with such slogans as "God bless you, my dear," "May all your dreams come true," and "Sleep with God's love."

Jaluit Atoll

Jabwor is that section of the series of connected former islets known as Jaluit that lies at the extreme northern end of the series and adjacent to one of the deep water passes, north of which, about a quarter of a mile distant, lies Enibor, another series of connected islets. The connection in each case is a sea-wall-protected causeway constructed by the Japanese to link the concrete forts and bunkers and gun emplacements. A handcart railroad is said to have run along the causeway. At numerous points the remains of forts, bunkers and heavy guns as well as shell cases, still stand. The seawall is generally about a foot thick, of reinforced concrete, broken by storm waves in places. The causeway sectors of the long islets resulting from the connections are often not more than 15-25 feet wide, with only Pandanus, Pemphis acidula and Messerschmidia as well as Scaevola tree growth, although various vines and weeds overgrow much of the ground. Many introduced decorative trees are found on Jabwor itself, which is the widest part of the islet of Jaluit. Few coconut palms remain here, although some young trees now five or six years old have been planted. The main growths since the end of the war have been Pandanus and numerous weeds. Many concrete platforms mark the location of former Japanese houses destroyed by bombs and shells during World War II; some are being utilized for new construction foundations for the Trust Territory's agricultural station at the tip of the islet adjacent to the pass, and for the settlement of laborers and the Protestant and Catholic missions and schools now being built up. Here is a good anchorage and a concrete pier in somewhat dilapidated condition. The southern part of the

settlement has an area set aside for the Kili people to use as a base for fishing and for warehouse and communication purposes.

Immediately south of the Kili sector the islet narrows to about 20 feet width and continues southwestward in varying and generally narrow widths until another former islet of some width is reached about three miles away. Here is a former pier and two 300-feet (?) high steel towers, one on the lagoon side and one on the seaside built by the Japanese for communications. The seaside tower is badly rusted through and unusable; the lagoonside tower is comparatively intact, and I climbed the ladder to the top for photos. The remains of large buildings lie adjacent to the towers, their concrete walls are still standing and possibly usable, if roofed over. Breadfruit trees in some number occur here as well as a dense growth of other trees. Little if any attempt has been made to clear the undergrowth that has sprouted up here since the end of the war.

Northward and across the channel from Jabwor, the islet of Enibor quickly narrows after an initial width allowing breadfruit tree growth and continues in 20-50 feet width for many miles interrupted now and again by gun emplacements and corroded guns and fallen-in-bunkers of concrete and coral rock. Over all these grow a "jungle" of atoll trees, shrubs and vines. Numerous crabs and an occasional brown rat rustled in the ground debris while lovely white fairy terns, white-capped grey noddy and now and then a reef heron flew overhead. The coconut trees growing here are all young. Much Pandanus has covered the area, with Messerschmidia and Scaevola prevalent on the seaward side, as well as occasional Pemphis acidula; Guettarda is more prevalent on the lagoonside or the interior. At one point on the seaward side were several large boulders torn from the reef edge and measuring about 6 feet cubed, having been pushed by storm waves to within 20 feet of the beach edge and 150 feet from the reef edge.

Imroj Islet next to an eastern deep pass of the atoll has a reported 300 people. The settlement looks rather shabby, but the islet appears productive. A striking amount of pandanus, bananas, and some lime trees grow on it. Breadfruit trees are low but numerous. Many squash or pumpkin vines were seen in blossom and appeared to be flourishing. On the northern end is a salt water basin fed by underground tidal flow in which mangrove thrives. A large but dilapidated Protestant church is a prominent landmark. Some Catholic converts also live here, including Jobjabot who sailed as crew member of Father Donohue's St. Joseph during my trip. The magistrate was absent, and a man named Karen took it upon himself to show me the courtesies of the place.

Kili Island

This lagoonless island is surrounded by a reef of rather narrow dimensions especially restricted on the leeward side. It is backed on this side by a sand beach in the southwest sector where small boat landings can be made through a 20-feet-wide channel at low tide. At high tide such landings are made with care directly on the rocky and bouldery shore. A high bouldery and rocky beach occupies most of the rest of the shoreline except a stretch

fronting the north end of the islet where sand again occurs. Salt water enters through coarse boulders into a brackish pond on the leeward side surrounded by a growth of Pemphis acidula which here also grows on the boulder rampart running inward from the beach. A fresh water swamp now planted partly in taro occupies the central part of the islet in back of the village proper. The highest point of land is occupied by the neatly thatched little church. The wooden houses furnished by the American authorities are not in very good condition and are ugly shacks at worst.

The islet has a high vegetation and is endowed with abundant rainfall as indicated by the damp soil and moulding piles of husks. It reminded me of Ringutoru Islet in Kapingamarangi, with a flourishing growth of Asplenium nidus and Nephrolepis hirsutula standing up to six feet high in the northern end where coconut trees also have been allowed to grow and sprout crowded together far too densely for good production. Small delicate mushrooms were observed, similar to those seen at Likiep and Jaluit. Moss covers the paths as at Nukuoro Atoll. The taro swamp, however, is badly tended, and overgrown with 2-3 feet tall grass and ferns. Much of the swamp is still unplanted and lying in waste and weeds.

In the swamp there was a large growth of a woody stemmed weed called mer (Jussiaea suffruticosa) by my guide. It has small yellow four-petaled flowers.

On the sandy leeward beach-ridge grows several kōno trees (Cordia subcordata) one of which is 6 feet in diameter one foot from the ground, but branches thereafter into limbs of about one foot diameter each. A Morinda citrifolia was seen with a trunk diameter of about one foot.

Some of the Kili people complain about not enough food and not enough variety of food, but there appear to be numerous breadfruit and a fair number of banana trees as well as coconut trees and some pandanus. Some 10,000 taro plants were brought in for them to plant, but the people are unused to its culture and apparently do not particularly like to work in the taro fields. They ate up the taro, often without replanting the tops, so that the stock is much reduced. While 210 or so people in 1956 may be rather too many for so small an area, food production from the land probably is greater than that from their erstwhile Bikini homeland, although they miss the rich lagoon fishing area. They appear not to be working too hard at improving their plant production, however.

Fishing is either on the narrow reef at high tide, or in the open ocean where it is restricted to the leeward side not far from shore. Five or six outriggers were used in line-fishing and a dozen men and boys were standing on the reef at high tide using goggles and spears for fish and mollusks. Before our schooner left about a dozen fish 7-9 inches long were bought or exchanged by our schooner's owner from the Kili people. The Kili store was the best stocked seen on the outlying atolls during our trip, although this does not indicate the buying power of the Kili people.

Kwajelein Atoll

The islets visited on Kwajelein had been violently disturbed by war activities and the vegetation was thus quite abnormal. The islets visited included five north of Kwajelein, of which Ebeje (commonly known as Ebeye owing to American usage) is the only one with a settlement, except for the one family living on South Loe Islet next northward of Ebeye. Northward of South Loe are North Loe, Bijinkur, and Eboj. Most of the latter three are under 100 feet wide, although Eboj is quite long. Scaevola is the dominant vegetation throughout Eboj, although Ipomoea pes-caprae forms a creeper mat in large areas. A few scattered Messerschmidia and a few Pandanus occur, with a few coconut trees here and there. Triumfetta procumbens also was prevalent in places and flourished better in the shade of Scaevola than in the hot sun adjacent, or, at least, showed larger leaves of greener hue, although having fewer blossoms in the shade.

North Loe was overrun with Wedelia biflora and Vigna marina in much the same way that Ebeje is. A few Guettarda trees occur and Messerschmidia is rather common here. Pemphis was not seen here, but my informant said that it was common on the small unhabited islets of the atoll. Its hard-wearing wood is used for husking sticks, for making canoe keels, and in the olden days, for spears.

Kwajelein Islet is just a large airfield with a military settlement and facilities. The Navy has a daily ferry service between Ebeye and Kwajelein Islets to take the Marshallese employees back and forth. Ebeye is a village of over a thousand Marshallese from many atolls who work for the Navy for their existence for the most part. On the islet is a Coast Guard Loran station (this operates a radio guiding system for ships), the Kwajalein Island Trading Company (Kitco), the Marshalls Import and Export Company (Mieco), a few small stores with pool tables, and the offices and residences of the Trust Territory Administrator. The latter is in the process of constructing new quarters but in the meantime lives in an old "temporary" housing unit left over from the war period. However, the Coast Guard sells them electric power for light, deep freeze and refrigerator, and they have a running water system derived from an elevated tank into which water is pumped from a concrete cistern collecting rainwater. Four or five small rooms in a building next to theirs serve as hostel accommodation for visitors.

Ebeye is depressing from a vegetatinn standpoint. Aside from a couple of small clumps of coconuts and a scattering of Messerschmidia, most of the vegetation comprises a half dozen varieties of weeds.

Likiep Atoll

The two chief residential islets lie at opposite ends of the long lagoon some twenty miles apart. Of these the most important by far is Likiep Islet and village on the east end. There also are a few residents in the other larger islets scattered along the reef. The shape of Likiep Islet is like that of a fishhook without the barb, the sharply curved part being in the eastern end, so that an excellent sheltered harbor is formed with sandy bottom

that is deep enough to accommodate the larger vessels that visit the atoll. The village is around this section of the harbor. At the end of the hook sand has been accumulating consistently, for a long period, and extending the shore line into the lagoon. A pier situated here now has its face 20-30 feet from the deep water that formerly was alongside, so a new pier extension has been built into the lagoon. Capelle DeBrum, one of the two leading men of the atoll, stated that so far as he had observed, no noticeable erosion of a serious sort had made inroads upon the land area of the islet from the oceanside.

The islet is not more than 300-500 feet wide being narrowest in the western end. Scaevola and Messerschmidia and some Pemphis cover the entire seaward strip for a depth of 20-50 feet. This has been left as a shelter belt intentionally to afford the coconut trees protection from the salt spray. The lagoon-side has been entirely cleared of weed species, and coconut trees grow right up to the edge of the beach. Breadfruit trees are abundant on the village end where the breadth of the islet is greatest. None appear more than 40-50 feet high and they are much branched close to the ground. The rest of the island is generally well planted to well spaced coconut trees, with occasional Pandanus and more rarely Calophyllum as an understory, although the latter are left as shade trees on the beach next to the village. The ground-cover is mostly grasses, some foot-high succulent weeds, entangled in some areas with Cassytha filiformis, the whole topped by a rather dense growth of arrowroot used here for food as elsewhere in the northern Marshalls after the breadfruit season, together with the pandanus which then comes into production more abundantly.

A striking topographical feature on Likiep Islet are the many large depressions on the western half of the islet, some round, some elongated, but with no special directional alignment. They reach down approximately to the surface of ground water. Several have been planted to taro, but some have coconut trees growing in them. An old man of 70 when asked about them said that he had heard that they had been caused by storms in ancient times, but he did not know how they originated. This appeared to be the opinion of other older men who did not believe they were dug for taro pits although some have been used for this. Today there is only a small amount of taro grown at Likiep. My opinion is that they were man-made taro pits dug before memory of the present people.

Major storms have come from the southwest and northwest. The last major storm was in 1918 when some 5,000 coconut trees were knocked over, but it was not a severe storm. There was no serious land erosion, although in several places on the lagoon side, accretion of land has taken place owing to sand accumulation. Water supply generally is plentiful, although occasional low periods occur when no rain falls in 3-4 months.

A localized growth of Wedelia biflora occurs on two sides of the path near the middle of the islet. Numerous patches of sandbur grass also bordered the path. The general aspect of the coconut plantation is very clean; all leaves and husks are piled up and burned. This injures some of the coconut tree trunks.

There are three varieties of breadfruit, moderately high yielding, with the producing season being from May to August; some production occurs in February.

The pandanus seasons are January to May and August to December, i.e., from August to May, thus taking the people through the period when breadfruit is not in season. Arrowroot (Tacca) is not planted but grows abundantly by itself. Food supplies are lowest in September.

Most of the coconut trees here date back to German planting by the ancestors of the present land-owners; a few were planted during the Japanese times. Two varieties of taro-plants grow here: Iraj (Cyrtosperma chamissonis) a large variety, and kotak (Colocasia esculenta) the true taro. Each family has a pig or two and a few chickens. Marbele (Ipomoea tuba) a vine, is fed to pigs. It has a white morning-glory type flower. Plumeria and Bougainvillea have been introduced as ornamentals. The outside fiber of Triumfetta procumbens is used for handicraft weaving, Pemphis wood for furniture and canoe keels, Morinda fruit for pig feed, and Calophyllum for boat keels and other parts having hard wear.

Some 3 or 4 poisonous varieties of fish, which everyone recognizes, occur in the lagoon or on the reef. Capelle reported that on Majuro a type of fish which had regularly been eaten for years had, about two years ago, suddenly become poisonous.

The wooden house with the tin roof is preferred here, particularly because it is used for water catchment and provides water much cleaner than that washed down from thatch with the latter's accumulation of insects, skinks, lizards, etc. Wood had been easy to get from salvage and scrap at Kwajelein after the war, but is now growing scarce. For a time it had been free for anyone to take.

Likiep has no large breadfruit trees suitable for canoe dugouts; formerly canoes were made from driftlogs, but in recent years driftlogs have grown quite scarce (possibly owing to change in lumbering or rafting operations in the northwest of the U. S.?). During German times there had still been some sea-going canoes, but western type boats were built and used for inter-atoll travel. Now canoes are all too small for this, and they also are rather few in number. During Japanese times, a large steamer visited the atolls once every two months, while smaller schooners made trips to each atoll once a month or oftener. Likiep has two locally owned schooners that operate between here and Kwajelein or Majuro. Transportation for Likiep, thus, is not a serious problem.

In June 1956 some 518 people were resident upon the atoll, most of them on Likiep Islet. About two-thirds of the local population is Protestant, and perhaps one-third is Catholic. The former have a large but unpretentious church whose pastor is Koneaea. The Catholic church is new, with a new rectory, nuns' house and school, all in bright aluminum and neatly laid out. The resident American priest is presently Father McCarthy whose schooner ran

on the reef at Kwajelein not long ago because the pilot and passengers were all asleep. His engine was rescued, but the hull was abandoned. Likiep is the center for Catholic girls' education in the Marshalls.

Before German times Likiep was temporarily uninhabited, but was visited by Wotje people from time to time for fishing, turtle and bird catching or for wood supplies. In the 1870's four men, an American, an Englishman, a German and a Portuguese combined their resources and bought the atoll from the Wotje chief who owned it. Actually, by tribal custom he did not have the right to alienate the land. A few years later, the American and Englishman sold out to the remaining partners and the atoll became the property of the Capelle and DeBrum families whose descendants remain the owners. It was not until then that coconut plantations were laid out, the owners hiring laborers from other atolls to come to Likiep to work for them. The latter eventually settled permanently as laboring families on the atoll and lost their outside connections as far as land rights elsewhere were concerned. Now these laboring families have been resident some 70 years and have nowhere else to go. They have no legal rights to local land, however, and work the plantations on a share-crop basis for the land-owners. The latter consist of the two clans, the Capelle with eight families, and the DeBrum with nine families. The original owners intermarried with Marshallese and subsequently with each other.

Capelle DeBrum is now recognized as head of the combined clans, while Melander DeBrum, his brother, is next in rank, and the two are at the top of the social and political hierarchy. Only one of the landowning families, Raymond DeBrum, is Protestant, the rest being Catholic, while most of the laboring families are Protestant. The economic conflict that has occurred between the landed and the landless is thus sharpened by religious division. Some of the landless recently have tried to make claim for property rights in land but have been unsuccessful. Dissatisfaction with earlier agreements for crop division recently brought on discontinuance of copra making work by many of the laborers, apparently supported by Raymond DeBrum, but the present arrangement of a 50-50 split of copra proceeds appears to have satisfied most of the laborers. Perhaps 25 per cent of them still are disgruntled and are not too active in producing copra.

A serious pest affecting breadfruit has been recently noticed (about a year or so ago). It turns breadfruit blackish-brown, spreading from an infected spot to the entire fruit which then becomes rotten. It was noticed first on one tree at the south end of the village, but this summer infestation was noted on several other trees, including one at the other end of the village. Small fruit flies fluttered about the rotten or diseased fruit, but these may be attracted by the spoiled fruit rather than by the disease carrier. Capelle expressed worry that their spread to all the trees would ruin this important food source for Likiep.

Lodo Islet is a quarter of a mile northward across the channel from Likiep village. Its aspect is similar to the plantation area of Likiep Islet. It is well cleared of undergrowth up to the shelter belt on the oceanside where a considerable growth of <u>Wedelia biflora</u> occurs. Attempts

have been made to burn it. In other areas the ground cover is much thinner than on Likiep Islet, reflecting a drier soil. Grass intertwined with Cassytha filiformis makes a thin mat. Six or seven houses are scattered along the lagoon side on the wider east end of the islet. Maas Hone, who recently completed his first year at the University of Hawaii, is the alab or head landowner of the islet, succeeding his father who died this spring.

On the west end of Lodo in the inter-islet channel the beach rock rises out of deep water in a coral cliff. A great slab had broken off due to erosion and undermining.

On walking along the lagoon shore with me, Maas noticed dense schools of small fish, sardine-like and 7-8 inches long. He got a throw net and, trailing the schools from shore, made a catch of about 150 fish after about 40 minutes and half a dozen throws of the net.

Maas informed me that there was at least one islet of small size along the reef that was covered with a tree whose description points to Pisonia. It was an islet with many nesting birds. In traveling westward close to the lagoonshore on the schooner, I observed an islet with vegetation that appeared to correspond to that of Pisonia. Many birds circled over it.

Liglaa Islet at the opposite end of the lagoon from Likiep Islet has its lagoon beach facing the prevailing wind. Vessels visiting this place sail out through the adjacent pass and anchor off the oceanside reef in the lee of the wind. After Likiep Islet, Liglaa has the largest number of residents. Actually, it comprises two islets close together separated by a few yards of channel. The larger one of the two, with a lagoonside beach is called Imejwa; the smaller is Maat. It took me about three hours of steady walking to encircle Imejwa. A remarkable and high sand beach with a crest 12 feet above high tide slants at a 30-40 degree angle to the water. From the crest there is a slightly sloping backshore which sometimes turns into a number of low dunes reaching inward 75-100 feet from the southeast end of the islet around to and along the east side.

The seaward side to the lee of the wind has a pronounced beachrock development in several well-marked strata sloping at 15-25 degrees dip. The channel to the north of the islet has what appeared to be raised bedrock in spectacular formations. They probably represent the remnants of islets formerly covered with soil now destroyed by storm action.

Along the sandy beach crest of the lagoon side and on the southeast end Scaevola is the dominant cover, with Cassytha throttling much of it. By contrast the northwest channel side and the ocean side find Pemphis forming a spray-burned and impenetrable shelter belt. The crowns of some of these show distinct alignments controlled by wind and spray.

The westward coast of the islet has sharply eroded bedrock standing several feet above the main reef flat. At the reef's edge here the lithothamnion ridges have a beautiful pink color, but this disappears in the leeward part of the reef.

The southeast sections of the islet are park-like and well-cleared. However, everywhere thousands of coconuts litter the ground, many well sprouted with half a year's growth, indicating the neglect that the laborers' dispute with the landowners has brought about. At the northwest sectors of the islet, neglect has permitted a rank growth of sprouting coconut trees 6-10 feet high, intermingled with Pandanus trees. The ground is heavily littered with leaf and debris among the young growth, so in places one finds the thickets impenetrable.

Majuro Atoll

Majuro is quite a large atoll, about 30 miles or so long - with numerous islets - including a large one, Majuro Islet about 4 square miles in area.

Uliga at the opposite end of the atoll from Majuro and where the Trust Territory District Administration is centered is unrepresentative but still exemplifies an essential part of the Marshalls' economic and social transformation and acculturation processes. Here an airfield with weekly connections by Trust Territory plane and occasional Navy plane, a motor road system, trucks and jeeps, wharf and terminal warehouses for ocean freighters, electric lights, hospital with medical and dental services, and more and better commodities at Kitco and Mieco, as well as a commissary with all essential foodstuffs, and a regularly paid staff, with money and things to be purchased, all occur. Here is the seat of overall government as well as the center of inter-island political relations and the site of the Marshallese Congress.

War damage to vegetation is apparent in the lack of well planted coconut plantations and in the overgrowth of weeds. Part of this is due to the fact that some land has been retained by the Trust Territory Administration, but is not being immediately used by it. Only when one gets away from this center does the vegetation situation become more normal in the sense of native plantations, as in the case of Enegu Islet, about three islets east of the pass, on the north reef. However, even here the situation appears affected by the nearness to the administration center of wage-paid labor, where cash is abundant enough so that urgency in working copra may not be pressing. Or, possibly, the owner of a large section of this islet lives far across the lagoon and seldom gets to Enegu to work his copra. The eastern two-thirds of the islet are overgrown with weeds and have sprouted coconuts strewn over the ground, the stage of growth of the latter indicating many months, possibly a year, of neglect, with sprouted nuts having fronds up to five feet or more in height.

On the west end of Enegu, a residential owner lived in an area newly planted with neatly rows of coconut trees about three years old. Immediately after the war or during the war, the area had been cleared for use by the Coast Guard according to my informant. This explained the uncrowded vegetation and new coconut plantations in straight rows as advised by the American agricultural aide.

Bananas and papayas are plentiful on this atoll, as is breadfruit. Taro is mostly lacking, however, and the people prefer to buy rice and flour as staple substitutes.

Maloelap Atoll

Airik and adjacent Makaru Islets on this atoll were visited by the writer in a Navy plane that landed in the lagoon. The former is the main residential islet of the atoll. The other islets in the atoll were heavily damaged by the war, as they were used by the Japanese for an air base and numerous installations and buildings with concrete platforms that have obstructed the replanting of the area with coconut or other fruitful trees. Wrecked planes and equipment and buried ammunition, unexploded shells and mines still cause the people to be fearful about clearing land and cultivating. Only recently a shell exploded without being touched or moved, and six ammo dumps or shells and a mine were exploded by a Navy demolition team sent there in July of this year. Such areas are overgrown with weeds and weed trees of many years growth, so that clearing them will involve much labor.

Airik Islet or Village appeared to be plentifully planted with productive breadfruit, pandanus and coconut. The breadfruit trees, however, are low, under 40 feet, as at Likiep. The islet is wide, about 1200 feet in sectors near the northern end. About 200 feet of this width on the ocean side, however, has been left as a shelter belt in which a rare pure strand of *Barringtonia* was observed, a stand about 150 feet across, a rather unusual feature on atolls. No taro pits are planted to taro, but old pits contain banana plants. No *Pemphis* or *Suriana* were seen on the ocean side, *Scaevola* being the predominant shelter belt tree, plus a few *Pandanus* and *Guettarda* and another shrub resembling *Scaevola*.

On Makaru Islet only the lagoonward third appeared to be cleared and with coconut uncrowded by weed trees, the oceanward two-thirds being a jungle of undergrowth including numerous young coconut sprouts surrounding the adult palms.

As seen from the airplane pink algae appear to cover the windward seaward reef-edge.

Mejit Island

Mejit is a relatively large island as islets on reefs go. It has two sections once separated by a narrow channel, but no separate names were attached to them. The larger section which has the greatest breadth was known as the "main island," the other section was merely called "that island" or "the other part." The channel appears to have been no more than 100 feet wide or less at the ocean side, broadening to 400 feet or more towards the lagoon side. There also appeared to have been an inlet or tongue of the "lagoon" into "that island." on the lagoon side which now constitutes a salt lake with a marshy fringe. The formation of this appears to have occurred during Japanese occupation times when the channel gradually filled in with

sand pushed in by the tide from the "lagoon side," so that now there is a broad sandy connection between the two parts, making the whole a single island surrounded by a reef. On the leeward side of the island is a narrow shallow "lagoon" hardly more than 150 yards wide and stretching along much of the leeward side. At low tide, it takes only about ten minutes to walk from the village along the almost exposed reef to the ocean edge of the reef.

The leeward beach is of fine sand and unusually high, appearing 15-20 feet from low water to beach crest. The southwest beach also is sandy but much lower. The vegetated area here runs inward from the beach crest in a sandy strip 250 feet wide; then the land suddenly rises 5-6 feet in elevation in a line roughly SE to NW.

The vegetation reflects the low rainfall and is similar to that found on the islets of Likiep, Utirik, and Ailuk. Breadfruit trees are low, but appear to do well and are productive. There are numerous papaya trees and some banana trees. The undergrowth below the coconut trees characteristically is a mixture of various grasses and rather dense stands of arrowroot (Tacca), with few weed-tree or bush species, although Pandanus trees are numerous. The aspect is park-like, and it is easy to walk in any direction across the island. On the east-southeast side a gradual rise occurs about 200 feet from the beach ridge. Ipomoea tuba, a morning-glory type vine, without flowers at the time of observation, forms a dense ground cover in places in the interior. Scaevola and Messerschmidia form a shelter belt on the ocean side here, followed on the inward part by a zone of Pandanus 20-30 feet wide. Inward from the east beach Cassytha filiformis forms a dense ground cover together with Lepturus and other grasses for a width inland of over 250 feet. Roads 6-7 feet wide, bordered with a line of coral stones, extend through the village and around the main islet, as well as through sections of the adjoining "that island." Many of these roads are overgrown with low weeds and grasses, however. 600 feet inland from the east shore Ipomoea tuba so covers the ground to a height of several feet as to constitute a serious impediment to walking. Here also are found some Morinda bushes of small size. Another 100 feet westward and inward and not far from the village are numerous taro pits, some well weeded and with a water-filled "drainage" ditch around the edge of the pit; others abandoned and not in use for taro. Breadfruit trees on the banks of these pits are scrawny and small, with trunks of under 1-2 feet diameter and with the main trunks generally broken off and rotten after reaching a height of 20-30 feet. Pandanus trees are also rather low, but are numerous on the half of the islet occupied by the village.

The old channel and part of the inlet that now has become filled with sand have been planted during the last two to five years with coconut trees, most of which are doing rather poorly, appearing chlorotic. The lagoonward or, rather, leeward part of "that island" also has a soil of nearly pure sand on which the coconut trees are low, chlorotic and often dead. In sections of the filled-in channel now planted with coconut trees, there still remain numerous clumps of Pemphis acidula to show that this once stood in salt water. Doubtless underlying the sand around the Pemphis there is solid rock commonly found associated with this tree or bush. Bruguiera type mangrove trees line the edges of the salt pond and are backed by Pemphis. Only this one species of mangrove was noticed.

One species of bush which was very common in parts of the interior was a low growing type called ulej by the inhabitants (Clerodendrum inerme). It has a white flower forming an incomplete circle of petals somewhat like those of the Scaevola. A similar plant, also called ulej (Pseuderanthemum carruthersii), is sometimes used for hedges around residence lots.

Flies were numerous and annoying; small swarms of them followed one even on the breezy windward side beach.

Namu Atoll

Our schooner made a landing on the leeward lagoon shore of Mai Islet of Namu Atoll. This islet showed an obvious change to a wetter climate in comparison with Maloelap. Mai is in the southeast end of the atoll. Coconut trees here are very tall and old, and the soil appeared black with humus and fertile. Breadfruit trees grew more than 90 feet tall, one was seen to be five feet in diameter at waist level.

The interior of the islet has a low swampy trough parallel to the shore. Coconuts sprouting 12-15 feet apart resulted in some crowding. Wedelia biflora weeds were rampant over much of the land. The soil surface was bouldery, with coconut fronds left about in disorder to rot. Morinda is a common understory tree with some Guettarda. Ipomea tuba grew on parts of the windward beach. On the southeast channel beach on the windward side of Mai grew some spray-burnt shrubs resembling Scaevola called ikung (Terminalia samoensis) by my informant. The burning method of clearing the underbrush had damaged some coconut trees in this part of the islet. A small pit with swamp taro was observed, the edges planted with banana trees. Only the single leaf type of fern (Polypodium scolopendria?) seen at Likiep was observed here, no Asplenium nidus and no Nephrolepis that characterize the wetter parts of the Marshalls. Prevalent weeds were Triumfetta procumbens, and a plant called kuli (Sophora tomentosa); a glossy-leaved tree called gizet and Bruguiera conjugata (called dzong) were observed.

The lagoon beach was clear of large trees and coconut trees for a distance of 20 feet back of the beach crest, and the sand was sparsely covered with grass and seedlings of Scaevola and Messerschmidia, indicating recent sand accretion.

The characteristic habit of Pandanus of sending aerial prop roots down from even upper branches was shown by an example of such a root reaching ten feet downward from the branch.

The taro-like plant called wot (Alocasia macrorrhiza), which is not edible, grew here in large numbers under the breadfruit and coconut trees. One taro pit was seen to be overgrown with weeds, while four breadfruit trees grew on its banks, each about a foot in diameter. The pit size was only 30 by 30 feet. Pandanus is the common beach-edge shrub, but I saw no Pemphis or Suriana.

There is some beach rock exposure on the lagoon shore in the north end of Mai Islet.

Across the lagoon from Mai, our schooner anchored off the leeward ocean side of the reef. On the rock flat of the reef near the pass there stands a huge boulder that appeared 6-7 feet high and perhaps 10 by 20 feet across, that must have been torn up from the reef edge by a storm wave. Observed in passing on the leeward side of the islet was a reef whose edge was only a few yards from the shore, the boulder rampart on the islet adjacent here appeared to rise 5-6 feet higher than where the reef edge was considerably farther out from shore. In an inter-islet channel on this same leeward (westerly) side of the reef, the reef flat was mantled with large boulders 3-5 feet in diameter.

Ronlap (Rongelap) Atoll

In conversation with me on 22 June 1956 Maynard Neas, District Administrator at Majuro, described briefly the problem presented by the people of Ronlap (Rongelap) about 100 miles east of Bikini. They were victims of the fall-out of the bomb test two years ago when some of them suffered mild burns, hair fall-out, etc. As a result the people were evacuated by Navy landing craft and removed to a small islet of 16-18 acres on Majuro atoll which was administration property. Here the United States had built them a village of wooden houses (plywood) and the community as a whole was given a subsidy of $1100 monthly.

The number of people evacuated from Ronlap included a few families in Ronrik (Rongerik) and Ailininae (Ailinginae), which two atolls were worked as plantations by the Ronlapese who owned them and the total was only 74 people. Their atolls lie in the dry zone of the northern Marshalls and are not very productive, especially during the winter dry season. However, there are said to be five or six square miles of land above high tide altogether, and the people subsisted all right. Their settlement in Majuro with a regular cash income, however, was somewhat of a bonanza, since they had to do little for a livelihood aside from picking a few coconuts for their immediate needs, and do a bit of fishing. A few breadfruit trees also offered some variety together with some papayas. The cash income or subsidy enabled them to buy at the trading store what they needed or wanted. This attracted very soon a large number of extended family members or relatives and friends from other atolls. Now, two years later, the total population of "Ronlapese" has grown to 175 people.

The AEC has been conducting tests for lingering radio-activity from fall-out at Ronlap and the neighboring atolls, and it appears that this is largely gone, so that the Ronlapese may be returned to their atolls soon. This involves the question of rebuilding the homes on the atolls and of transporting the people there from Majuro atoll. The AEC has promised the Ronlap people that it would construct a new village for them, wooden houses similar to or better than the ones they now occupy on Majuro, and it inquired as to how many wanted to return. The Ronlapese were also informed that the subsidy would end with their return and they would again be on their own as before the tests of the bombs took place. The answer was rather surprising, since instead of a few more than the original 74 people that might be expected to want to go back, all of the 175 people now in the settlement wanted to go there. Mr. Neas thought that possibly the great attractions

were the wooden-tin-roofed houses which, although merely small one-room affairs, nevertheless provided a drier place to live and lasted a longer time without repairs than native houses. There possibly also has developed a community esprit-de-corps which may be a factor in the desire of the whole group to move there rather than for the hangers-on to disperse to their original areas of residence. Finally, there perhaps also may be some wishful thinking that in spite of the announced intention to discontinue the subsidy, the Americans might still subsidize them in some way.

Captain P. C. Staley, Commander of the Kwajelein Air Base, informed me that the problem of furnishing transportation for these people back to Ronlap had been dumped into his lap. He had not decided yet whether he would send them back by air or boat. Mr. Neas thought that the best way would be to send one or more landing craft to take the whole community at one time, as had been done when they were removed from Ronlap.

<u>Utirik Atoll</u>

Utirik Atoll has few islands, and they are not large. The residential islet of Utirik is the largest, possibly 2500 feet long by about the same depth, roughly triangular, but with almost a mile of attenuated strip of bare sand in addition westward.

There are several rather unusual features about this islet. Along the north side of the eastward bulge oceanward and running for about $\frac{1}{4}$ mile toward the lagoon with a width up to 100 yards, is one of the largest boulder and cobble beds and ramparts I have yet seen among the atolls. Much of it is bare, the rocks and cobbles turned black and gray with algae. Most of it, however, is covered with a wide stand of <u>Scaevola</u> shrubs. As the shoreline turns towards the southwest, an equally unusual sand beach and backshore development takes place, with a width of about 200 feet. This also is mostly covered with <u>Scaevola</u>, but with occasional <u>Messerschmidia</u>. On the south side of the island, where it abruptly narrows, the sand beach also narrows and is bordered by a long strip of exposed beach rock inward of which the ground has been scoured out by a typhoon which occurred, according to my informant, during pre-Japanese times, possibly the one of 1905. The beach rock extends with characteristic oceanward dip for a distance of more than a mile. Inward of it a desert-like expanse of sand and gravel stretches for a width of 500 feet and narrows as the end is approached. On the lagoon-side of this patch is a second line of beach rock, this time dipping down toward the lagoon and having a fine texture which shows clearly its origin from lagoon sand. A new ridge of sand has been built up lagoonward of this to a height of 5-6 feet and is covered with grass and occasional <u>Scaevola</u>. The large sand patch has scattered clumps of <u>Pemphis</u>, <u>Scaevola</u>, and <u>Messerschmidia</u>, and in one central spot, also half a dozen coconut trees with nuts. Most of it is bare, however. Because of the lack of cobbles and boulders in this scoured-out remnant of former vegetated land area, it can be assumed, perhaps, that the storm-wind came from the direction of the lagoon. This same wind probably accounts for the large sand beach development on the south side described above. The nature of the exposure and the position of an adjoining islet to the northeast would indicate that the storm wind probably swept across this section of the islet from a westerly direction.

A ten-feet long sawed-off section of a log three feet in diameter had drifted on to the southeastern sand beach. On it were cut the names Ole, and also Ha, and there was a blue-pencilled name, Halleck. Probably the log came from the northwest coast of the United States.

In the southwest end of the islet exposed to the sweep of the north or northeast wind from across the lagoon, the results of a second storm appear. This storm occurred in 1951, and brought the fall of 10-20 per cent of the coconut trees then standing. The trees lie fallen toward the south to southwest directions. Exposure of the roots shows the depth of the main roots to be about 2½ feet in a smallish clump less than 3 feet in diameter, with sand as the soil constituent.

The plantation vegetation is similar to that at Mejit and Ailuk. Arrowroot (Tacca) is omnipresent and quite dense, grasses of several species together with a fair amount of Triumfetta procumbens form the ground cover. Breadfruit trees here as elsewhere in the northern Marshalls are low, mostly from 20-30 feet high, some of the young vigorous ones well rounded and forming a beautiful tree. Few had trunks over a foot in diameter. This is partly explained by the fact that perhaps many, probably most, large breadfruit trees were blown over in the 1951 storm. Some black fungus or other disease had attacked many of the leaves of some trees observed. There were some abandoned taro pits in the interior, but I was told that no taro was being grown.

ATOLL RESEARCH BULLETIN

No. 55

Agricultural notes on the Southern Marshall Islands, 1952

by

William H. Hatheway

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AGRICULTURAL NOTES ON THE SOUTHERN MARSHALL ISLANDS, 1952[1]

by
William H. Hatheway

On Arno Atoll several instances of low productivity of coconuts were observed. The Marshallese recognize at least two types of "poor coconuts:" "laora" and "mellal." Both conditions appear to be related to local soil conditions, although many Arno people attribute "mellal" to the presence of demons. Lajibili, former magistrate of Arno, called the writer's attention to a malady affecting breadfruits. Since there appears to be no native name for this condition, the term "brown rot" is suggested. On the southern field trip of September 18-27 the occurrences of "laora" and brown rot of breadfruit were investigated. In addition, notes were made on all local agricultural problems which appeared sufficiently important to warrant attention.

Laora in its most extreme form is characterized by:

1. Yellowing and scorching of the leaves of the coconuts. The tips of the leaves and leaflets are most severely scorched. Areas adjacent to the midribs are usually green.

2. The leaflets of the coconuts are sometimes twisted and more or less knotted together.

3. Dead leaves tend to hang on the tree, giving it the appearance of a Washington palm.

4. The trunks are sometimes blackened.

5. Density of stocking is low — about 40 trees per acre in the worst affected areas of Arno. This is about 1/3 the stocking of the more productive groves.

6. Dead trees are conspicuous. About 35 trees per acre are dead in the worst affected areas of Arno.

[1] The information recorded in the notes presented here was gathered during the brief visits to the several atolls mentioned during the official field trip of September 18-27 to the southern Marshall Islands. It was written up for the use of the District Administrator and his staff and was mimeographed for very restricted distribution to staff members. Since there appears to be no probability that the information will be worked up into any further publication, and since there are original observations, not available elsewhere, Dr. Hatheway has consented to the reproduction of his memorandum to the District Administrator for the users of the Atoll Research Bulletin. It has here been reproduced in exactly its original form, without further editing except change of title. — Editor's note.

7. The older trees are mostly barren of fruit, although they produce inflorescences. Apparently the fruits abort at an early stage of development.

8. The younger trees bear fairly well; the water is exceptionally sweet.

9. In the worst affected areas of Arno the ground cover consists of

a) Clumps of Fimbristylis cymosa ("Relijman"), covering the ground between which is a leathery black blue-green alga (unidentified as yet) resembling a crustose lichen.

b) Tacca leontopetaloides ("Mokmok" or "Arrowroot") is common. Its leaves are yellow except along the veins and are characterized by circular brown spots 1/8 to 1/4 inch in diameter.

10. Abandoned coconut groves are invaded by the following species of plants in roughly the order listed:

a) Wedelia biflora ("Marjej")

b) Premna obtusifolia ("Kar")

c) Artocarpus altilis ("Breadfruit:" variety "Bukaral" most common, spreading by root suckers; variety "Mijwan" invades by seed)

d) Pipturus argenteus ("Arme")

e) Morinda citrifolia ("Nen")

f) Guettarda speciosa ("Wutilomar")

g) Allophyllus timorensis ("Kitak")

h) Pandanus tectorius ("Erdwan")

11. "Laora" is restricted to the centers of the wider islands. Most of this land was formerly in breadfruit forest, scattered throughout which were pits in which the Micronesian taro (Cyrtosperma chamissonis or "yaraj") was grown. Since the advent of copra culture much of this land has been given over to the growing of coconuts.

Laora is here tentatively attributed to a deficiency of available phosphorus, although the opinion of many of the more sophisticated Marshallese that it is due to a lack of salt (sodium chloride) should not be dismissed without further investigation. Phosphorus deficiency is suggested by:

1. The analyses of Dr. E. L. Stone (Atoll Research Bulletin Nos. 5-6, November 15, 1951), who found only 10 pounds of available phosphorus per acre in a sample of soil from an area of poor coconuts on Arno Island.

This is less than 10 percent of that available in productive groves.

2. Field evidence from Ebon Atoll, where there are local phosphate deposits in the interior of Ebon Island. The coconuts on the soils on or immediately adjacent to the phosphate deposits are vigorous and bearing heavily, whereas "laora" is restricted to the non-phosphatic areas of the same island.

3. The oily nuts of the coconut contain relatively large amounts of phosphorus, as do most seeds. The abortion of the fruits at an early stage suggests a deficiency of an essential element. The sweetness of the nuts that are formed may indicate that the sugars are not transformed into proteins. Phosphorus is an essential constituent of nucleoproteins, which tend to occur in high concentrations in seeds.

4. "Laora" is restricted to certain local areas, on which other species of plants totally unrelated to the coconut — e. g., Tacca — show similar symptoms. This makes it extremely unlikely that "laora" is to be attributed to the presence of insects, nematodes, pathogenic fungi, bacteria, viruses, or other pests.

"Mellal" is easily distinguished from "laora". The symptoms are:

1. General yellowing of the leaves of the coconut. New leaves tend to remain yellow for long periods of time.

2. The coconut trees appear stunted and probably die early. Trees in "laora" areas are often very tall.

3. Dead leaves do not fall readily.

4. The trees bear only a few nuts.

5. Ground cover is invariably depauperate. It consists chiefly of an open stand of bunchy Lepturus repens ("ujoij" a grass). The parasitic vine, Cassytha filiformis ("kanong") is usually abundant. Intsia bijuga ("kubuk") grows as a straggling shrub, although on better sites it becomes a tree often common.

6. The soil is a nearly unaltered gray sand containing very little organic matter. The soil of "laora" areas, on the other hand, is a black loamy sand containing as much as 30 percent organic matter.

"Mellal" was observed on several islands of Arno Atoll, usually at or near lagoon or ocean shores. Stone's analysis of a "mellal" soil suggests a nitrogen deficiency, although excessive salinity is possible in some cases. It is extremely likely that many instances of "mellal" can be traced to ancient typhoons. In the course of these large quantities of sand and rock fragments were thrown up on the land, or the topsoil was washed away. The resulting soils are immature and contain little organic matter or

available nitrogen. It is suggested that the planting of native leguminous ground-cover plants be encouraged. These would tend to build up the nitrogen and organic matter content of the soil. The plants best suited for this purpose are the creeping vines Vigna marina ("markine-jojo") and Canavalia spp. ("marlap").

"Mellal" is a common but very local condition. The affected areas are usually less than 5 acres in extent. Since it appears that intensive research into this problem by agriculturists of the Trust Territory would not yield returns commensurate with the time and money invested, no attempt was made to study the distribution of "mellal" in the southern Marshalls. "Laora," on the other hand, is a problem of major importance. Over 200 acres on Arno Island alone are in poor coconuts or secondary forest. About 60 tons of copra per year could be harvested from this area if the condition were corrected. This would increase the cash income of the atoll by about 10 percent. Moreover, the presence of a considerable source of phosphate rock at Ebon Atoll suggests that if "laora" is correctly attributed to a lack of available phosphorus, the condition might be quickly and inexpensively remedied. This would also, of course, provide income to the owners of the Ebon phosphate. The distribution of "laora" in the southern Marshalls is:

Atoll	Islands	Remarks
Arno	Arno	Very severe
	Ine	Slight
Majuro	Majuro*	Not seen
Ebon	Ebon	Severe
Namrik	not present	
Kili	not present	
Jaluit	Jaluit*	Not seen
	Pingelap*	Not seen
Mille	Mille*	Not seen

* Not visited by Field Trip ship, but reported by native informants.

Brown Rot of Breadfruit

The writer has observed this condition only on the variety "Bitaktak," although Johnny Silk, the school principal of Ebon Atoll, stated that he had seen it on "Bukaral". "Bitaktak" is the preferred variety of breadfruit, at least in the Southern Marshalls.

Symptoms are:

1. Lumpy or knobby appearance of the fruit, similar to that of the seeded variety "Mijwan." Normal "Bitaktak" is much more nearly a perfect ellipsoid.

2. Abnormally small size of the fruit.

3. Discoloration of the rind. Brown, roughly circular spots an inch or more in diameter appear on the surface of the fruit. This discoloration may extend to the core, but more commonly the portion of the fruit immediately beneath the brown rind is ripe, although the rest of the fruit remains unripe. That is, the flesh beneath the brown spot is yellow, soft, and has a fruity odor, instead of being white, firm, and nearly odorless (Bitaktak is normally picked green). In severe cases very small fruits may ripen and rot completely without falling from the tree.

Some informants stated that this condition was merely one of normal ripening, and that it occurred chiefly at the end of the bearing season, presumably on fruits which the owner had neglected to pick. Others said that they had noticed it only very recently. There was some disagreement as to the year in which the condition was first observed. The writer collected specimens of diseased fruits (pickled in 70 percent alcohol) and associated insects (copra bugs and fruit-fly larvae), and took color photographs of healthy and "diseased" fruits. Although the condition may not be abnormal or pathological in any sense, it merits further study by agriculturists of the Trust Territory. The distribution of brown rot of breadfruit in the southern Marshalls is:

Atoll	First Observed		Remarks
Arno	c. 1935;	spread from Arno Island	Severe
Majuro	c. 1936		Not seen
Ebon	c. 1945		Severe
Namrik		Apparently not present	
Kili		Apparently not present	
Jaluit	c. 1949		Severe
Mille		"Always present"	Severe
Aur		Present; informant; Johnny Silk	
Caroline Islands			
Moen (Truk)		Present; informant: Johnny Silk	
Mortlok		" " " "	
Losap		" " " "	

The Phosphatic Rock at Ebon

Near the lagoon shore of Ebon Island four groups of piles of phosphatic limestone and soil were observed. Two groups of piles consist of chunks of phosphatic rock about 0.2 cubic feet in size. The piles are 125 to 150 feet long, 25 to 30 feet wide, and 3 to 5 feet high. Total volume of these piles is estimated at 64,000 cubic feet. Two other groups of piles consist of loose phosphatic sand and loam. The piles are roughly triangular in shape, and their total volume is about 25,000 cubic feet. The total volume of phosphatic rock and soil in the piles is thus approximately 89,000 cubic feet.

Assuming a density of about 1.7, the weight of the phosphatic rock and soil in the Ebon piles is about 5,000 tons.

According to local informants this phosphate was dug in the interior of Ebon Island by Ebon people under the direction of the Japanese and stored in specially constrected warehouses near the lagoon awaiting shipment. Several shiploads were sent to Japan, but American bombers prevented the loading of the remaining phosphate by destroying the warehouses and the miniature railway which facilitated loading. The phosphate workers were paid wages by the Japanese, but the owners of the land from which the rock was removed were not compensated, the phosphate being regarded by the Japanese as Ebon's contribution to the Imperial war effort.

The phosphate diggings in the interior of Ebon were visited. Although probably more than 50,000 tons of phosphatic rock and soil were removed, considerable amounts still remain -- perhaps 50 to 100 thousand tons.

Considerable deposits of phosphatic limestone were also observed at Takleb Island, on Arno Atoll. According to Felix, the magistrate of Arno, whose family holds land rights on Takleb, pineapples, tomatoes, bananas, and papayas formerly grew well there. Several members of the Trust Territory staff at Majuro have expressed desires to grow these plants. If phosphatic soil were transported from Ebon to Majuro, perhaps these and other desirable crops could be grown in places sufficiently protected from salt spray. A more significant use of the Ebon phosphate would be the possible alleviation of "laora" on several atolls of the southern Marshalls.

The Mille Mekinono

A "Mekinono" (a variety of breadfruit with deeply incised leaves) was observed at Mille, which, according to the local school teacher, bears the year around. Since all varieties of breadfruit in the Marshalls -- including Mekinono -- are usually strictly seasonal in their fruiting habits, this tree may prove to be extremely valuable. The variety is propagated vegetatively by root suckers, so that all its offspring should have identical fruiting characteristics. It is suggested that suckers be purchased from the owner and grown at Majuro. Grafts on small stocks of other varieties might be attempted. A special search should be made for non-seasonal varieties of breadfruit and pandanus and for plants of those or any other species the fruiting times of which do not coincide with the majority of varieties. These should be collected and studied in a central experimental garden. It is possible that eventually exchanges might be effected between the Marshalls and other Pacific Islands. The Marquesas, for example, are rich in cultivated varieties of breadfruit the fruiting seasons of which may possibly be different from those of the Marshallese varieties. Similarly, the Gilbert Islands possess many horticultural varieties of pandanus not found in the Marshalls.

The Mille Mekinono stands in front of the council house on Ngalu Island. It is said to belong to Laibon.

Notes on Insect Pests

A coconut tree infested with insects on Mille was pointed out to the writer. Larvae and adults of the insect were collected.1/ The damage did not appear to be severe.

At Jaluit "white grubs" were reported on the leaves of the breadfruit.

The agricultural situation at Kili

The Bikini people now living at Kili Island have for at least the last two years relied heavily on imported foods. During the brief stop at Kili an attempt was made to assay the agricultural situation. The following food plants were observed:

1. Coconut. Although the growth and productivity of the trees appears excellent, copra production is not high (c. 60 tons/year). Most groves are very poorly maintained. Apparently little attempt has been made to cut back the brush, a common practice elsewhere in the southern Marshalls. In some places the undergrowth of "Arme" (*Pipturus argenteus*) and "Kangal" (*Pisonia grandis*) is so thick that collection of fallen coconuts must be nearly impossible.

Pandanus. The Bikini people relied heavily on Pandanus on their home atoll.. They have only 4 or 5 cultivated varieties at Kili, whereas at Bikini they probably had 20 or 30. The trees are by no means abundant at Kili, and there apparently is not enough of the thatching variety ("Benuk") to provide roofing material.

Yaraj (Micronesian taro -- *Cyrtosperma chamissonis*). In the interior of Kili Island stands a fresh-water swamp at least 20 acres in extent. This is eminently suitable for the cultivation of yaraj. Although a few yaraj patches were noted in the swamp, they appeared to be neglected, and over 95 percent of the swamp was overgrown with weeds, especially *Jussiaea suffruticosa* and *Ipomoea tuba*. Over 1000 pieces of yaraj were collected at Ebon and presented as a gift to the people of Kili.

Kutak (Hawaiian taro - *Colocasia esculenta*). A few neglected plants of two varieties were observed in the interior swamp. At the council meeting the people requested instruction in the cultivation of this important food plant.

Sweet Potato (*Ipomoea batatas*). Several patches were observed. The plants appeared healthy and well cared for. Instructions for cultivation were requested.

Breadfruit. Varieties Bitaktak and Bukaral present. There is ample potential breadfruit land. Some young trees have been set out, but many more could be planted.

1/ *Brontispa chalybeipennis* Zacher, according to Dr. J. L. Gressitt. Distribution: Ponape, Kusaie, Marshalls.

<u>Wöt in Kabiling</u> (<u>Xanthosoma</u> sp. or "yautia"). This is a taro-like plant cultivated in upland well-drained soils. Several patches were observed. The plants appeared to be well tended and are thriving.

<u>Mokmok</u> (<u>Tacca leontopetaloides</u>; "arrowroot"). Only one plant observed. This is an important food plant elsewhere in the Marshalls. It requires no care, and more should be introduced.

<u>Bananas</u> (<u>Musa</u> spp.). Bananas are planted in and around the village. A good deal of potentially valuable banana land is not being utilized.

<u>Banke</u> (<u>Cucurbita pepo</u> -- pumpkin). Several plants observed.

<u>Kurak</u> (<u>Inocarpus fagiferus</u> -- Tahitian chestnut). One mature tree.

<u>Kotel</u> (<u>Terminalia catappa</u> -- Indian almond). One immature tree.

At the council meeting a request for turkeys was made. Turkeys were formerly common in the northern Marshalls, but were confiscated by the Japanese during the war. Whether they would be successful in the wetter southern Marshalls is a matter of conjecture. Ducks and chickens are thriving at Kili; the former take full advantage of the central swamp. It is suggested that domestic geese be introduced to Kili instead of turkeys, Geese are large, hardy, fast-growing birds, and are able successfully to forage at large with virtually no supplementary feeding.

The general impression is inescapable that the resources of Kili are not being effectively utilized. The interior fresh-water swamp could easily produce yaraj sufficient to feed twice the present population. The coconut groves are sadly neglected. Banana production could be trebled in a few years with very little effort. It is my impression that the Kili people regard their present home as strictly a temporary one and are unwilling to invest labor on crops that they may never harvest. Indeed, the feeling may exist that if the resources of Kili were effectively utilized, the American authorities might decide that the situation was satisfactory. That is to say, by making a satisfactory adjustment to Kili the Bikini people might irrevocably prejudice their chances of returning to Bikini. Certainly the attitude that Kili is considered unsatisfactory was made very clear at the council meeting. The problems of Kili, however, are not basically agricultural.

<u>Rats</u>

On Jilang, Kejbwe, and Enidrik Islands of Arno Atoll rats damage a considerable proportion of the coconuts, by eating through the sides of the green nuts and extracting the milk and soft meat. These rats are said to be small and grey.

On the Possible Use of Dynamite

At Jaluit and Mille several small bomb craters were observed. In most cases the ground water was exposed in the pits. This suggested that taro pits might be conveniently excavated by the judicious use of small explosive charges. The method would be especially applicable on Mille Island, Mille Atoll, where the Japanese constructed their major airstrip in the southern Marshalls. It is impracticable for the Marshallese to attempt to dig taro pits through the cement runways of this strip, but the work could possibly be done cheaply and effectively with explosives, under the supervision of a competent civil engineer.

At Namrik and Kili copra loading operations are at best inefficient and at times actually dangerous. At Namrik copra is loaded from the shore into flat-bottomed boats, which are dragged across the ocean reef flat to a relatively high Lithothamnion ridge. The latter is exposed at low tide. At this point the heavy bags are transferred to Mokil boats, which are parked on the Lithothamnion ridge. The Mokil boats, are then towed or rowed to the field-trip ship. A channel blasted in the ocean reef flat from the Lithothamnion ridge to the shore would enable the Mokil boats to dock at the beach and be loaded directly.

General Remarks

At Council Meetings the Marshallese were especially eager to discuss agricultural problems. It is obvious that the Marshallese themselves have neither the training nor the economic means to investigate the causes and treatments of "laora", brown rot of breadfruit, and similar problems. Some technical assistance is necessary. Indeed, a program which had as its purpose the study of agricultural problems would seem to be one of the most concrete ways of "helping the Marshallese to help themselves." Such a program would involve at least the following provisions:

1. Periodic inspection and inquiry into local problems. This was attempted on the present field trip.

2. Detailed investigation of major problems. Field observations and analyses of soil suggest that phosphorus deficiency may be the cause of "laora," but experimentation in the field is necessary to test this hypothesis. Such experimentation could be conveniently accomplished on Arno Island, but it might require the continued presence of the investigator for several weeks. The Japanese agriculturists are said to have made long sojourns on several outlying atolls.

3. Collection and study of indigenous and introduced economic plants in a central experimental garden. This is essential to any long-term plan for the improvement of existing varieties and would form an important element in the training of the agriculturist himself. Few Americans have had first-hand experience or training in the cultivation of breadfruit or Micronesian taro, for example. Such a garden would serve also as a center for exchange of promising economic plants with other regions of the Pacific.

ATOLL RESEARCH BULLETIN

No. 56

Atolls visited during the first year of the Pacific Islands Rat Ecology Project

by

J. T. Marshall, Jr.

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Atolls Visited During the First Year of the Pacific Islands Rat Ecology Project

by
J. T. Marshall, Jr.

I. Acknowledgments

In connection with studies of rats on a typical Pacific high island, Ponape, comparative observations were made on outlying atolls. The Pacific Islands Rat Ecology project, supported by the National Science Foundation and the U. S. Public Health Service, is administered by the Pacific Science Board, with transportation provided by the Office of Naval Research and the U. S. Trust Territory of the Pacific Islands. These notes do not include definitive information on the rats, which will be treated in the official reports of the Pirate Project. Rather, they are intended to give a general impression of the little-known animal life of the atolls. I thank Mr. Del H. Nucker, High Commissioner of the Trust Territory, and his staff for innumerable courtesies and assistance which made this work possible and a pleasure; I thank also Mr. Henry Hedges, Ponape District Administrator, and his staff for facilities and for transportation. I am indebted to Oliver Nampei and C. E. Howell for hospitality and passage to and from Ant Atoll, and to Yeswo and Peter Marshall for assistance in the field work. I am grateful to the residents of the various islands for their hospitality.

II. General Remarks

In contrast with Arno Atoll in the Marshall Islands, the atolls of the Ponape District have a richer flora, providing a greater variety in the shapes and sizes of the plants. The vegetation is denser, the trees are taller, the undergrowth is luxuriant, and there are more epiphytes - all indicating a much more humid climate. There are more nesting sea birds. Because of their nearness to high islands such as Ponape, Kusaie, and Truk, there is a greater chance for the occurrence on them of land birds. The usual resident noddy terns (two species), black-naped tern, crested tern, and fairy tern were seen on high and low islands alike. Non-breeding shorebirds were generally distributed: *Pluvialis dominica*, *Numenius tahitiensis* (rare), *Heteroscelus incanus*, *Arenaria interpres*; on the other hand wintering *Actitis hypoleucos* and *Calidris acuminata* were seen only on Ponape. The toad *Bufo marinus* was found only on Guam, Ponape and Lele I., Kusaie. The land snail *Achatina fulica* was seen only at Ponape, Truk and Guam.

III. Descriptions of Certain Caroline Atolls

Mokil Atoll

I visited Kalap Island from 8 a. m. to 4 p. m. of November 29, 1955. Mokil Village is arresting in the beauty of its blue and white wooden houses on stilts, the orderliness of its coral pavements, the precise con-

struction of its stone landing piers and beautifully thatched boat houses and cooking houses (the same community organization and pride is reflected in the Mokil homesteading area at Ponape). For an atoll islet, Kalap is unusual in its great width, high elevations (hills of perhaps 25 feet), and enormous taro swamp, with the huge taros planted in rows.

In the tall forest, coconut husks, fronds and branches, though neatly piled at intervals, provided habitat for rats. One Rattus exulans was shot as it climbed a tree. About the town were domestic cats, pigs, ducks, and chickens. Reef herons (Demigretta sacra) are kept as pets, and are venerated (as the species name implies) as symbols or "ancestors" of certain families.

Carl Dannis, an educated Mokilese with extensive training as a sanitarian and as an assistant to the Rat Ecology project, stated that the Japanese used Manton Islet as a wharf and warehouse area, and that it was still over-run with large rats, presumably Rattus rattus; whereas he suspected that Kalap had possibly only R. exulans. He stated that the white-browed rail (Poliolimnas cinereus), which he well knew from live trapping at Ponape (specimens, not previously recorded from Ponape) occurred in the taro swamp. Although I saw none in the few minutes I looked there, I consider his report reliable.

Pingelap Atoll

Like Mokil, Pingelap has a tiny lagoon and broad land area for an atoll. There is a mangrove swamp in the lagoon. Huge pandanus trees lining the shore screen the village. During my visit from 1:30 to 5:00 p. m. on November 28, 1955, which was sunny and clear, there was a strong breeze. But the air was dead still in the tall jungle of huge coconut palms, breadfruits, pandanus and bananas of the interior. Ferns abounded both on the ground and up the trunks of the trees. There was much clearing of undergrowth, with the brush, logs, and husks piled in long rows. Again this neat arrangement offered better hiding-places for rats than if the material had been left scattered. A fairly large rat, possibly Rattus rattus, ran along such a wall of branches, and a young R. exulans was taken from a nest in a coconut stump. As at Mokil, huge skinks (Riopa albofasciolata) prowled among the pigs in their penned areas. A tame reef heron and a pet booby (Sula) were seen in the village. Anous tenuirostris and Gygis alba were nesting in the breadfruit trees at the outskirts of town.

"Atoll Strand" of Kusaie

Around the south and east border of Kusaie is a narrow coral strand with coconut palms, piles of coconut husks, Scaevola, tall pandanus, vines, and rank undergrowth. It is exactly like an atoll therefore, and I mention it here to show what land animals and birds can occur in a typical atoll environment which is very close to a source of colonists. My visit at this "coral strand" was only during November 25-26, 1955, and I cannot be certain that all the land birds live permanently there. All are species which made

long flights over the lagoon. Yeswo and I trapped and collected on a part of this strand connected to Lele Islet by a rock causeway. On the ocean side of the strand is a sand beach, then a lagoon, then an outer reef; on its inner border is mangrove swamp, then a rushing tidal river, then the steep forested mountains of Kusaie proper.

On Kusaie itself a richly tawny or reddish form of Rattus rattus occurs. But the Rattus rattus collected on the strand were predominately the black or plain brown varieties which prevail on Lele, the port; these were seen crossing the causeway in broad daylight. This means that the rat population of the strand is considerably isolated from that of the mainland.

Ant Atoll; Southern Portion

Peter Marshall and I stayed at Pohn Sanghi Village on the islet called Pukennge (Nikalap Aru I. on hydrographic chart) from December 9 to 12, 1955. We visited Imuntiati Village and hiked to the western extremity of this islet, Panmuk. Coconut palms are throughout planted in rows with varying heights of undergrowth according to the time since trimming. At intervals along the shore, every 50 yards or so, are large native trees, in which most of the land birds were found. Breadfruits and tall symetrical pandanus trees are present. The smallest islets, with beautiful sand beaches, have denser stands with more native trees such as Scaevola and Messerschmidia, and there are Pemphis and a few Sonneratia along the lagoon beach. At the broad west portion of Panmuk was a dense jungle, overgrown from former coconut plantings, with large remaining forest trees (with holes in which lorries were evidently nesting), a lush undergrowth including ferns and a taro swamp. There was much rain during our stay. Doubtless Ant gets much rain from the clouds which concentrate at windward Ponape.

Roof rats (R. rattus) raided copra drying sheds by day; these and R. exulans were trapped in abundance. None was seen in trees during night hunting. Domestic cats, dogs, pigs, and chickens occur. A school of porpoises played at the entrance to the lagoon; these animals performed double flips and double twists with ease in their jumps out of the water.

Ant Atoll, Alona (Wolauna) Islet

This remote islet at the northwest corner of the atoll was visited from May 14 to 16, 1956 by Peter Marshall, Yeswo and myself, in order to see what animals might occur in the untouched natural vegetation. All kinds of vascular plants that I could see were collected, and identified by F. R. Fosberg (I inadvertently missed Morinda, which was common, judging from fruit lying on the ground). The configuration of the vegetation may be judged from the following notes on the plant collections:

No. 153 Derris trifoliata Lour.
Small seedling growing in coral sand just within woodland edge at shore. No others seen.

No. 154 Terminalia samoensis Rech.
Large tree, shiny leaves, trunk 2 feet in diameter. Abundant at periphery of islet, but back of Messerschmidia.

155 Polypodium scolopendria Burm. f.
Growing from rhizomes in patches in shade on coral ground. Also on large horizontal trunks of Messerschmidia. Common.

156 Cenchrus echinatus L.
Creeping and erect on coral ground at edge of woods just behind usual camp ground. Only the one patch, 10 feet across.

157 Pisonia grandis R. Br.
Smooth pale bark, roots sprawl over coral, many vertical shoots from big trunks. Abundant in interior.

158 Messerschmidia argentea (L.f.) Johnst.
Large tree in bloom, flowers white, and small green berries. Checkered dark bark. Abundant just along shore.

159 Pandanus tectorius Park.
Only one individual present. Few prop roots, just about 8 inches off the ground. Tree 12 feet tall, single trunk pale, bulges above ground. Leaf $6\frac{1}{2}$ feet long.

160 Asplenium nidus L.
Huge plant growing on coral ground in shade. Leaves $4\frac{1}{2}$ feet long. Only 2 others seen, both near this one; one of them was dwarfed and was growing out of a half coconut shell.

161 Cocos nucifera L.
Four or 5 old trees in center of islet, other seedlings planted and ringed with coral walls; other seedlings at far shore look as though the nuts have washed ashore and grown.

Note: No Scaevola sericea was seen on this islet.

The nearly elliptical islet is about 400 feet long. It is composed of jagged coral boulders built up to a peripheral rim with gravel and sand, but sunken and exposed in the interior sink. The shore is of coarse sand and gravel surrounded by a hard coral pavement covered at high tide and strewn with black coral boulders. A long white coarse sand spit extends southward about 200 yards. On it a large colony of Thalasseus bergii had abandoned their fresh eggs, which seemed to have been rolled by a high tide. The birds protested our presence and dived at us but never returned to their eggs.

Gygis alba and Anoüs tenuirostris nested in the trees; many of the latter's dense population were dead and dying. Droppings were profuse but I saw no actual deposits of guano; the material seems to drain out from the coral interior, though it must contribute to the raised dark sandy border. The

dominant vegetation is the dense closed canopy of Terminalia, Pisonia, and Messerschmidia about 30 feet high. All other plants seem to be accidental or local. Part of the raised loamy border is clear and park-like beneath the canopy; either bare or with "lawns" of Polypodium.

In late afternoon hundreds of frigate birds (Fregata minor) and boobies (specimen sent to USNM) gathered, circling overhead, and after dark they began to land in the trees, all coming in from the same direction.

Five or six reed warblers (Acrocephalus luscinia), a large population for so small an islet, sang constantly in the trees. Only a couple of house flies were noted despite the numerous dead noddies. We were bitten by long-legged delicate flies a little smaller than the house fly. Cockroaches and ants (including a biting kind) swarmed over the whole islet. One earthworm was seen. Small crabs set off most of the rat traps and tiny hermit crabs abounded. No herons, rats, bats, toads or snails were found.

Oroluk Atoll

Yeswo and I visited Oroluk on June 5-6, 1956. This huge atoll is mostly an elliptical reef, with only a small islet at one end. This has a natural forest with Pandanus understory at the west end, open plantings of coconut palms in the central part, and a large papaya garden with taros and dense weeds. At the edge of the beach is Messerschmidia and some dense grass. Pisonia grandis, Morinda, Calophyllum and Asplenium nidus were seen. The ground is of white sand at the beach, followed inland by larger coral fragments, and the interior has stinking black mud from bird droppings. Three men from Kapingamarangi were staying at the island; they had captured 27 adult female green tortoises, which were taken back to Ponape. These had been laying eggs in the beach sand. Others were seen in pairs in the lagoon. Domestic pigs and chickens were present. Eleven roof rats (R. rattus) were trapped, mostly in the thatched buildings. These were all remarkably alike in color even to a white spot on the chest. This gives the impression of inbreeding within the progeny of perhaps a single recently-introduced pregnant female -- in marked contrast to the heterogeneity typical of all other rat populations I have trapped in Micronesia.

Invertebrates noted were small day-biting mosquitoes, large coconut crabs (which carried off the rat traps), purple square land crabs, ghost crabs on the sand, hermit crabs, katydids. There was a large nesting colony of Fregata minor and boobies (Sula -- apparently both S. sula and S. leucogaster) in the native trees to the north.

I estimated the dense population of starlings (Aplonis opacus) at about 400, 95% adults. They differed visibly in size and color, suggesting a mixed stock. Families of juveniles begging food from their parents were dusky ventrally with indistinct streaking. But I saw at least one grown bird whose ventral color was white with clear black streaks. Some of the calls of these starlings differed from those on Ponape. They were shabby as if heavily parasitized (as were my specimens with mites).

These tame birds entered the houses. They spent much of their time in the very large papaya gardens and left none of the fruit for human consumption. The Kapingamarangi people used a slingshot against the birds, with which I collected two. Both had mended serious bone fractures yet were of normal behavior. This starling also occurs on Kapingamarangi Atoll, reported by Niering in Atoll Res. Bull. No. 49.

Conclusions on nesting and roosting oceanic birds. --

Unlike the small noddy terns and fairy terns (which roost and nest successfully on inhabited atoll islets) the large boobies, frigates, and terns are limited to seldom visited islets such as Alona and Oroluk. Native policies of preserving nesting sanctuaries for turtles and large oceanic birds should be encouraged.

IV. Distribution of Resident Land Vertebrates on Caroline Atolls, 1955-56.

On the accompanying table the fauna of the high islands, presumably the source of some of the animals of atolls, is entered for comparison as is that of Arno Atoll, Marshall Islands. Kusaie was visited November 23-27, 1955, Ponape from August 1955 to July 1956; Moen I., Truk from June 20 to 28, 1956. All the following were observed in numbers and are presumed to be permanently established and able to carry out their entire life cycle on the island indicated. The Ponape mountain starling is still established over a large area of forest, but is very rare.

Table 1.
Distribution of resident land vertebrates.

(Islands are arranged from west to east, distances apart in miles entered between their names).

Animals / Islands	Truk	Oroluk	Ant, Wolauna I.	Ant, Pukennge I.	Ponape	Mokil	Pingelap	Kusaie (coral strand)	Kusaie	Arno
Distances in miles, approx.		235	185		10	100	65	165		600
Rattus rattus	*	*		*	*		?	*	*	*
Rattus exulans	*			*	*	*	*		*	*
Rattus norvegicus					*					
Mus musculus	*				*					
Pteropus (large, not molossinus)	0			0	*				0	
Emballonura					*					
Deer (2 species)					*					
Cat, feral					0					
Pig, feral										
Dasia smaragdina	0	*		*	*	*	*	*	0	*
Emoia of Truk	*									
Emoia boettgeri		*		*	*	*	*	*	0	*
Emoia arnoensis										*
Emoia cyanura	0	*		0	*	*	*	*	*	*
Striped bronze Emoia	0			*	*	*	*		*	
Leiolopisma noctua ?	0				*	0				*

* Specimens collected and deposited in U. S. National Museum, some duplicate bird skins are in the collection of the Southwestern Foundation of Vertebrate Zoology, Los Angeles.

0 Observed but not collected

Table 1. (cont'd)

Animals / Islands	Truk	Oroluk	Ant, Wolauna I.	Ant, Pukennge I.	Ponape	Mokil	Pingelap	Kusaie (coral strand)	Kusaie	Arno
Distances in miles, approx.		235	185		10	100	65	165		600
Riopa albofasciata	0	0		*	*	0	*			*
Gehyra oceanica	0			*	*	*	*		0	*
Perochirus articulatus				*	*					*
Lepidodactylus lugubris	0		*	0	*	*	0		0	*
Gymnodactylus pelagicus					*					*
Demigretta sacra	0			0	0			0	0	*
Nycticorax caledonicus	0									
Ixobrychus sinensis	0									
Anas superciliosa	0									
Gallus gallus, feral in jungle	0				*				0	
Poliolimnas cinereus					*	?				
Ptilinopus porphyraceus	0				*				0	
Ducula oceanica				0	*				0	*
Gallicolomba xanthonura	0				*					
Trichoglossus rubiginosus				0	*					
Asio flammeus					*					
Collocalia inquieta	0				*			*	*	

Table 1. (cont'd)

Animals / Islands	Truk	Oroluk	Ant, Wolauna I.	Ant, Pugennge I.	Ponape	Mokil	Pingelap	Kusaie (coral strand)	Kusaie	Arno
Distances in miles, approx.		235	185		10	100	65	165		600
Halcyon cinnamomina				0	*					
Edolisoma tenuirostre					*					
Acrocephalus luscinia	0		0	*	*					
Rhipidura rufifrons					*					
Myiagra oceanica	0				*					
Metabolus rugensis	0									
Aplonis opacus	0	*		*	*	*			*	
Aplonis pelzelni					*					
Myzomela cardinalis	0			*	*			*	*	
Zosterops conspicillata	0				*					
Zosterops cinerea					*			*	0	
Rukia sanfordi					*					
Erythrura trichroa	0				*					
Lonchura nigerrima					*					

* Specimens collected and deposited in U. S. National Museum, some duplicatesbird skins are in the collection of the Southwestern Foundation of Vertebrate Zoology, Los Angeles.

0 Observed but not collected.

Conclusions on reptiles. — There is no impoverishment of the lizard fauna on sizeable atolls remote from the high islands; for instance, the faunas of Ponape and Arno (Atoll Res. Bull. #3) are practically identical, and have the same number of species, though each has one species not found on the other. Therefore the lizard faunas of atolls are independent of proximity to high islands.

Inasmuch as the 1955-56 lizard collections have not yet been identified by experts, I merely assume, through familiarity in the field, their identity with species on Arno. In case my suppositions are wrong, the following descriptions are offered for provisional identification:

Diurnal Skinks

Dasia smaragdina large, green (with color polymorphism: olive, brown, black); trees.

Truk *Emoia* medium-small, brown above, light gray beneath; ground and vines.

Emoia boettgeri medium, brown above, yellow below; ground.

Emoia arnoensis medium, black; ground.

Emoia cyanura small, dorsally striped, bluish tail.

Striped *Emoia* small, bronze back, striped sides, pale venter; ground.

Leiolopisma noctua? small, bronze back, blackish sides, pink beneath; under leaf litter.

Riopa albofasciolata very large, dusky above, pink beneath, black hash-marks along lower jaw distinguish even the juveniles; ground.

Nocturnal Geckos

Gehyra oceanica large, tail narrow; arboreal.

Perochirus articulatus medium, tail like arrow-head; houses.

Lepidodactylus lugubris small, tail like arrow-head; houses, trees.

Gymnodactylus pelagicus medium, no frills on toes; ground.

Tentative conclusion on birds.--- Several kinds of land birds can occupy the atoll environment where a high island is a nearby source of replenishment (within sight, as at Ant).

V. Non-native birds on atolls

Kwajalein I., Kwajalein Atoll, Marshall Islands.--- On June 11, 1950 I saw a mynah (*Acridotheres tristis*) perched on the main airport building. During several days' stay in July 1956, I noted at least a half-dozen at the gardens around this same building, now used as a nursery. They were eating papayas.

Wake Island.--- During a sojourn on July 19-21, 1955 I saw a male English sparrow, *Passer domesticus*, alight on the quonset at the west end of the Transocean Airlines BOQ area on July 20th.

The ease with which non-native animals are now being transported is illustrated at Guam, where the following were unheard-of in 1945. I saw at the U. S. Naval Hospital (June 28-July 15, 1956) several pairs of tree sparrows, *Passer montanus*, and a small flock of rice birds, *Munia oryzivora*. In addition the musk shrew, *Suncus murinus*, is now common, and there are reliable reports from sanitation officials of a large green snake and an anopheline mosquito.

ATOLL RESEARCH BULLETIN

No. 57

Preliminary report on the flora of Onotoa Atoll, Gilbert Islands

by

Edwin T. Moul

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PRELIMINARY REPORT ON THE FLORA OF ONOTOA ATOLL, GILBERT ISLANDS

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Edwin T. Moul

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This report represents the second part of the preliminary report on the work of the General Naturalist, from June 15th to August 30th, on the Pacific Science Board's 1951 Expedition to Onotoa in the Gilbert Islands. The project was supported by funds granted to the National Academy of Sciences by Contract N7onr-291 (04), NR 388-001 with the Office of Naval Research. The generous cooperation of the U. S. Navy Department, the U. S. Coast Guard, and the Military Air Transport Service is acknowledged.

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INTRODUCTION

The report on the animals of the atoll has been published in the Atoll Research Bulletin #28, May 31, 1954. A preliminary report on the Geology of the atoll by Dr. Preston E. Cloud, Jr. can be found in the same publication #12, December 15, 1952.

The atoll of Onotoa (see map), totalling 5.2 square miles of land, is divided into 3 large inhabited islands designated as North Island, South Island and Tabuarorae and four quite small uninhabited islands known as Aonteuma, Abanekeneke, Nanntabuariki and Abeinringan. A population of approximately 1800 people live in this small area, hence all land that is at all useful has been planted in coconut groves. The smaller islands are primarily of coral gravel soils and supported a few coconut trees, with the exception of Nanntabuariki which had only scattered shrub growth. Sixty species of flowering plants have been identified. About 15 of these which are cultivated were confined to the village areas. A few species were represented by only one or two plants on the whole atoll.

VEGETATION

Coconut groves

Most of the land on the larger islands was covered with coconut trees. Small groves were also present on two of the smaller islands. The groves were generally made up of randomly scattered trees of varying heights and ages; a

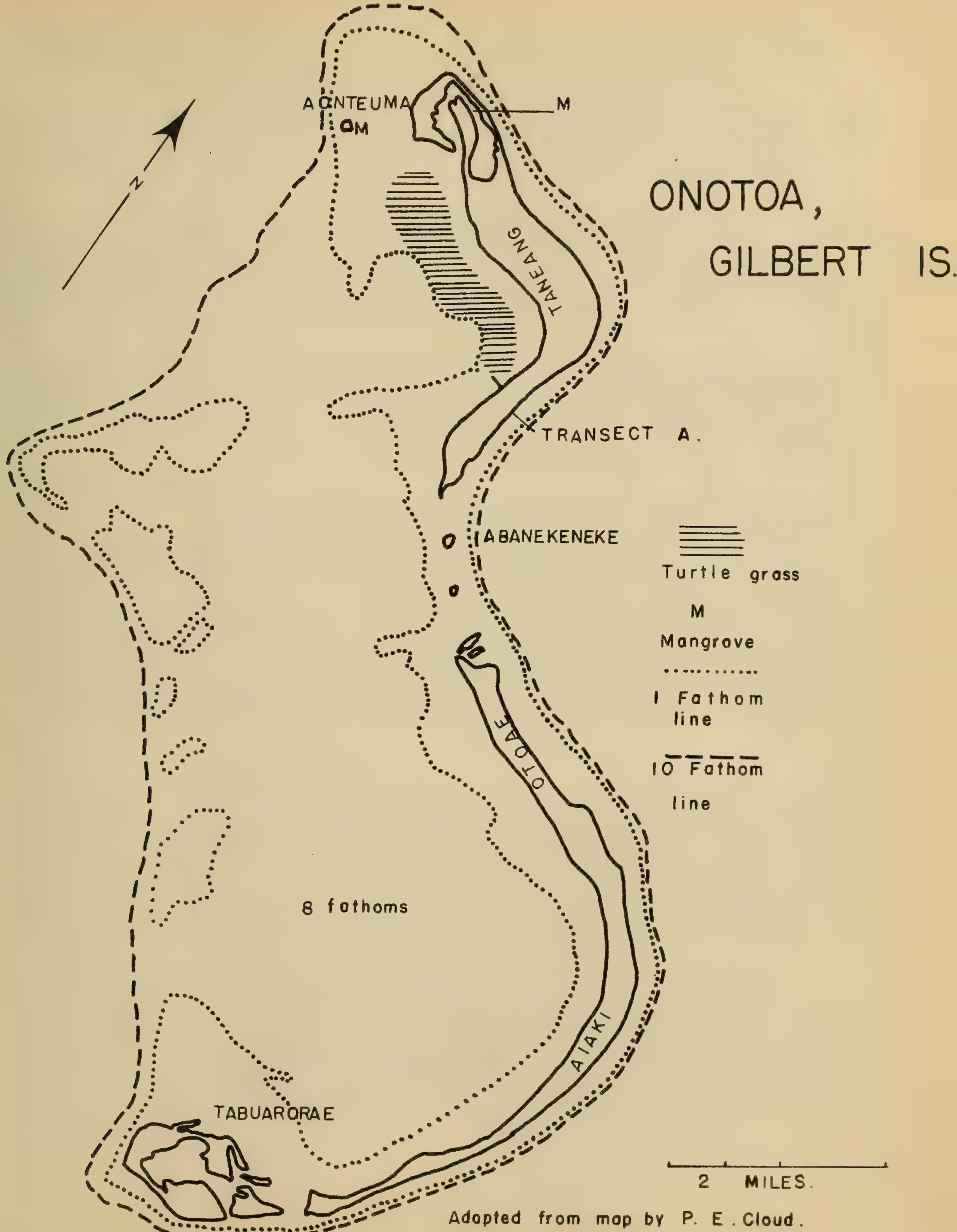
few recently planted ones (on formerly inhabited sites) were in regular rows and of uniform size and age.

The aspect of the coconut plantations varied with their location on the atoll, with the substratum and ground water conditions. Dense stands of coconut palms forming a continuous canopy, grew on the limesand soils (Cloud loc. cit., pp. 22, 58). Such vigorous groves were typical of the lagoon side of the islands, along the village road. They formed dense shade and had few understory plants. Young coconuts and Pandanus were usually present. Near the villages a few Ficus trees were found in these groves and appeared to have been planted. In the more or less well tended dense plantations, the soil surface was usually bare, except for a few grasses and herbs, Lepturus, Stenotaphrum, Euphorbia, Sida and Fimbristylis all growing widely scattered. In many areas an accumulation of fallen leaves and husks littered the soil and may have contributed to the sparseness of ground cover vegetation. The densest stand of Stenotaphrum observed on the atoll formed a complete ground cover in a grove on the North Island, where the soil surface had been cleared of all litter. Adjoining our camp site also on the North Island was a stand of coconut trees reported to be 15 years of age. These trees were planted in regular rows and were of uniform height. The owner had kept the soil clear of litter and in the dense shade the herbaceous vegetation grew widely scattered.

In contrast to these heavy groves, were the thin, irregular stands, usually located down the center of the large islands and on the seaward side, but generally on lime sand soil. Since the canopy was quite open, the understory here was well developed and showed an increased number of species. Messerschmidia, Guettarda, Pandanus, Scaevola and young coconuts formed the understory and, in some cases, very dense thickets. The ground cover here was also more extensive and consisted of mixed or pure stands of Sida, Lepturus, Fimbristylis, Triumfetta and Euphorbia. Blue-green algae and mosses covered the soil in many places between the clumps of herbs.

A few very poor groves occurred on the three larger islands on lime sand soil, but were more common at the exposed extremities of these islands on fine coral gravel soil and on the small islands of Aonteuma and Abanekeneke where the soil was also coral gravel. These stands consisted of a few widely scattered trees, usually old and sometimes infected with bracket fungus. The understory where developed was a dense thicket of Scaevola and Guettarda. The ground cover consisted of the same herbs listed above.

The effect of the recent year and a half of drought (1949-50) could be seen near the south end of South Island. The width of the island at this point is only about 50 feet from lagoon beach to seaward ramparts. The fresh water lens must have completely disappeared or become so shrunken that salt water penetrated into the soil, for nearly all the coconut palms were dead in this area. Scaevola, Pandanus and Guettarda did not show any serious effects.


ONOTOA,
GILBERT IS.
N
AONTEUMA
M
M
TANEANG
TRANSECT A.
ABANEKENEKE
Turtle grass
M
Mangrove
1 Fathom line
10 Fathom line
OTOAE
AIAKI
8 fathoms
TABUARORAE
2 MILES.
Adapted from map by P. E. Cloud.

Clearings

At intervals along the length of North Island occurred irregular clearings. There were no indications as to their origin. Lack of plantings and/or carelessness on the part of the owners may have been the reason for their existence. The soil appeared to be the same as in the best coconut groves.

In these clearings were found scattered thickets of Scaevola and Guettarda with some Pandanus and an occasional tree or clump of Messerschmidia. Many babai pits (taro) had been dug throughout this area. Generally one or two Messerschmidia trees were found growing at the edge on the mounds of earth. The dead leaves of this tree were gathered, piled up and later used as mulch around the Cyrtosperma (babai) plants in the pits.

The ground cover consisted of large irregular clumps of Sida fallax, Lepturus, Portulaca and Euphorbia chamissonis. In many cases these patches were of one species only. The bare areas of white sand between them had a broken crust of blue-green algae (Scytonema spp.) with mosses growing on it.

Area of Brackish Pools

East of the village of Buariki on North Island and at the northern end of South Island were two areas of brackish pools. The soil was a silty lime type termed "caliche" by Cloud (loc. cit.). Widely scattered coconut trees were growing there. They were dwarfed and did not seem to bear a heavy crop of coconuts. Pemphis grew around the edges of the pools and in small thickets. Young coconut trees occurred in the understory, even in great abundance, on South Island. On North Island only scattered culms of Fimbristylis were present with crusts of blue-green algae covering much of the bare sand between them. On South Island the ground cover in this area was more lush and included Lepturus and Portulaca.

Vegetation of the Seaward Ramparts

Thickets of Scaevola grew on top of the ramparts and showed signs of damage by salt spray on the seaward sides. Pandanus also grew sparsely along the top of the ramparts or back of the Scaevola either singly or in groups, and also showed signs of damage by salt spray. However some of these plants were able to produce large fruits in this situation. Messerschmidia was less common on the ramparts than Pandanus, occurring now and then on the crest. Cassytha was rare here, but occasionally grew on Scaevola.

On the inner slope of the ramparts, the vegetation was sparse and scattered, with areas of white sand between. Few coconuts grew on the slope, but the groves started at their base. Scaevola bushes grew on the slopes and down into the groves. Pandanus, Messerschmidia and Guettarda were more common on this slope than on the ramparts. Cassytha was rare here, but did parasitize Scaevola. Culms of Fimbristylis, alone or with Lepturus, were spotted here and there. Sida fallax and two species of Portulaca were also part of this community.

At the north end of North Island the rampart vegetation consisted of a pure stand of Pemphis. These shrubs attained a height varying from 10 to 15 feet and formed almost solid hedge-like thickets, broken by the paths made by the natives going through to the seaward reef.

Vegetation on Gravel Soil

At some places on the seaward side of the islands, on the northern point of North Island and on Aonteuma, Abanekeneke and Nanntabuariki the soil consisted of coarse and fine gravels. These were areas reached by waves and probably flooded during periods of storms. A few isolated Scaevola and Guettarda bushes were conspicuous against the bareness of the area. Some small Pisonia trees were found here, their leaves badly damaged by leaf cutting bees. Pandanus and Morinda citrifolia were represented by occasional dwarfed specimens. Lichens were collected on the bark of Guettarda growing in this habitat on Aonteuma.

The chief herbs on these areas were both species of Boerhavia, Sida fallax and the two species of Portulaca. The Boerhavia plants were large and the total spread of single plants reached as much as 8 feet. These were distributed widely, some growing in the shade of the Guettarda or Scaevola shrubs, while others were in the open. The few Sida plants were large and shrubby, but showed yellowing of the foliage. The Portulaca plants were in isolated clumps or as scattered individuals. Cassytha was common on the Guettarda and Scaevola bushes.

Further back from the shore line coarse coral fragments graded into finer fragments. The vegetation remained primarily the same, with the addition of a few isolated coconut palms. Premna was common on Aonteuma island on this fine gravel. Lepturus and Phyllanthus were additional ground cover plants, but only the latter really common.

Pisonia Groves

Some scattered Pisonia trees were located on the coral gravel areas on Aonteuma Island and on the north end of North Island, but on Tabuarorae there were two distinct narrow groves of large trees over 40 feet in height. These groves were on a ridge of indurated phosphatized limesand soil and the odor and droppings under these large trees indicated a big bird population. The nests of the smaller noddy tern were occupied at the time of our visit on July 25th. The soil was bare directly under the trees except for dead branches and fragments of logs, all soft and spongy. However, on both sides of the groves the vegetation was the most luxuriant seen on the atoll. The greatest number of species were also noted here. The predominant understory plant was Ficus, but young breadfruits, papayas, both flowering and bearing fruit, Guettarda, Pandanus and young coconuts were also present. A wide variety of herbaceous plants covered the ground under this shrub understory.

Vegetation around Fish Ponds & Sand Flats

At the north end of North Island was a large fish pond which ended in extensive sand flats, partially flooded at high tide. The greatest concentration of mangrove, Rhizophora mucronata, bordered the fish ponds and grew on the part of the sand flats flooded by the tides. The only other mangroves observed were 2 trees and many small seedlings growing in the shallow calcareous sand of the embayment between Aonteuma and North Island.

The wetter sand flats, flooded at very high tide, had a heavy stand of mangrove that extended almost completely across. The fish pond was almost completely encircled by mangrove thickets growing in the shallow water. Back of the mangroves on higher ground was a zone of Pemphis, and coconut palms beyond the Pemphis.

The bottom of the fish pond was covered almost completely with turtle grass, Thalassia hemprichii. Green algae, mostly a species of Microdictyon, grew as epiphytes on the turtle grass.

The highest sand flats appeared to be dry most of the time and were flooded at only extreme high tides. The central part of these flats was bare white sand riddled with burrows of fiddler crabs. Pemphis formed a shrub border, but all of the shrubs that had grown far out on the flats were dead, only those along the edge were still living. Groves of coconut palms grew down to the edge of the flats.

Babai pits (Taro pits)

The cultivation of Cyrtosperma for food was quite extensive on the atoll. Pits had been dug to a depth of 15 feet in the limesand soils in the center of the three large islands. Many of these were in the areas described above as clearings. On Tabuarorae there were many abandoned pits.

Since these pits were generally moist or flooded shallowly with water from the fresh water lens, algae samples were taken in many of them. Blue-green algae, Phacus and Rhizoclonium were common. Complete identification of the fresh water algae from these pits is being made.

A variety of flowering plants grew in these pits. Eleocharis geniculata and Cyperus laevigatus were common, the latter was quite abundant in several abandoned pits on Tabuarorae. The only banana plants seen on the atoll grew in one of the babai pits. Several large shrubs of Jussiaea suffruticosa were found growing in a pit east of the village of Aiaki.

The pits varied in size, but usually were between 25 and 30 feet long, with a width of 10 to 20 feet. Mr. Richard Turpin, the British Land Commissioner, told me that in some cases as many as 10 individuals owned little plots in a single pit. In many pits the natives had built up the humus around the largest plants by using mats of coconut leaves to form a circular wall and then had filled this with the leaves of Messerschmidia and

Guettarda along with the blackish sand found under old trees of these species. Some of the larger babai plants were flowering. Only in a few cases were the plants in a single pit of the same size.

Vegetation of sand dunes

On the southern tip of North Island, the southern tip of South Island and the northern tip of Tabuarorae are a series of low sand dunes. These areas are hot during the middle of the day because of their exposure to the sun. The white sand between the scattered shrubs causes an extreme glare.

The principal shrubs were Scaevola, Guettarda and Pemphis. These were the only shrubs present in this community on North Island, but on South Island and Tabuarorae Suriana, Sophora and Terminalia were also growing. Suriana, however, was common only on Tabuarorae. Cassytha had parasitized a number of these shrubs. Grasses and herbs were rare and since the sands were apparently shifting from time to time, no moss nor algae were present.

SPERMATOPHYTA

Sixty species of vascular plants were collected or observed by the author on Onotoa between June 24th and August 30th, 1951. In the following species list is included a short account of the occurrence and abundance of the plants. Native use is included whenever observed or learned. The author's collection number follows the name of the island on which collections were made. Native names obtained are included only if supplied by more than one authority. The first and second set of plants are deposited in the U. S. National Herbarium and the Herbarium of the Bernice P. Bishop Museum at Honolulu. The other duplicates are in the Chrysler Herbarium at Rutgers University, New York Botanical Garden, Gray Herbarium at Harvard, University of California Herbarium at Berkeley and the private herbarium of Dr. F. R. Fosberg.

Angiospermae: Monocotyledonae

PANDANACEAE

Pandanus tectorius Sol.

North Island 8364, 8412.

A list of native names supplied by our cook, Baru is given below. He also supplied information on the use made of some of these varieties by the natives.

te aramaru) both with small phalanges, leaves
te aramarieba) used for mat weaving.
te bakororso
te ulonau
te aramoroia

te iribaikawa
te tina
te iritawatawa - tall straight trunk, used for supports in house building.
te aranteba
te annabai
te irikiri
te iriauriaria - large fruited variety, blackish cast on leaves

This is one of the three important plants in the native economy. It grows on limesand soils under the coconuts and on the fine gravels. Salt damaged specimens grew on the ramparts and a few stunted ones on the coarse gravels.

At one spot on North Island, new plantings had been made by taking a crown from a branch, tying the leaves together and planting these cuttings rather deep into the soil. These new plantings were in irregular rows in the shade of coconut trees.

The ripe fruit is known as "te tou". The fruit is taken apart and cooked, then the pulp is pressed from the base of the phalanges and spread on Guettarda leaves to dry in the sun. During the drying process the mass or pudding is usually covered with flies. It is called "te tuae". If this pudding is mixed with water, as a soup, it is then called "te kabubu".

HYDROCHARITACEAE

Thalassia hemprichii (Ehrenb.) Ascherson

Lagoon 8188.

Large beds of this aquatic plant were found in the north end of the central lagoon along the shore of North Island at the village of Taneang. The plants were deeply rooted in the limesand bottom and the leaves were only about 6 inches long. These beds were covered at low tide. The plants grew so densely that they caused the deposition of sand and fine silt. The green alga, Microdictyon, and a small gelatinous red alga were very abundant, both attached and floating among these weeds. Halimeda stuposa also grew in these areas. The bottom of the fish pond at the northern end of North Island was almost completely covered with Thalassia and many fish and invertebrates were present in the weed patches and on the individual plants.

GRAMINEAE

Cenchrus echinatus L. "te anti".

North Island 8386; South Island 8206.

Found in just two sites on the atoll: thick solid stands are common along the road north of the village of Aiaki, and several single plants were growing along the road on North Island at our supply dump, south of the Government area. It seems certain this is a recent introduction and will probably spread undisputed over the atoll before long. The native

name given is the one used in the northern atoll of Makin and was supplied by Jim Redfern, our interpreter from Makin.

Lepturus repens (Forst.) R. Br.

North Island 8019, 8454; South Island 8212.

The commonest grass on the atoll, found on all the islands, the largest stands on the limesand soil, but rarely forming a turf. On the poorer soils, only widely scattered culms were present and usually in association with Fimbristylis cymosa. Scattered clumps grew on the seaward beach ramparts. The most vigorous plants were found along the lagoon roads.

Stenotaphrum micranthum (Desr.) Hubb.

North Island 8055, 8155.

The second most important grass on the atoll, restricted to the three large islands. It was found growing on limesand soil in the dense shade of coconut groves. It was also rather common around the edges of the babai pits in full sun. Many of the stands of this grass were dense and continuous in contrast to those of Lepturus. In the grove north of the Protestant Church, in the village area of Buariki on North Island was found the heaviest and largest stand anywhere on the atoll, covering almost completely a 5-acre tract.

Eragrostis amabilis (L.) W. & A. "te uteute ni mwaane".

North Island 8130, 8339; South Island 8207.

Found as a turf at various places along the village road on both North and South Islands. Also common along paths in the center and north end of North Island. On Tabuarorae it grew on a narrow piece of high ground between the lagoon and the shrubby growth on the sand flats. Growing mixed with Cenchrus on South Island.

Wherever this grass was seen the soil seemed to be wet and dark in color with a great amount of humus. It was usually found only on the finer soils in which there were few or no gravel particles.

Eragrostis whitneyi Fosb. "te uteute ni mwaane".

North Island 8090, 8316.

Confined to North Island. Growing on limesand soils along the lagoon road and along a path in a sunny area in the center of North Island. Common where it was found.

CYPERACEAE

Cyperus laevigatus L.

Tabuarorae 8224.

Collected only on this island in an abandoned babai pit. The bottom of the pit had a very shallow layer of water and the soil was held firmly by the roots and rhizomes of the plants. Formerly it was used for weaving.

Eleocharis geniculata (L.) R. & S.

North Island 8158, 8337; South Island 8210.

Growing in some of the babai pits on North and South Islands. Not abundant in any of the pits.

Fimbristylis cymosa R. Brown "te uteute ni aiine".

North Island 8021, 8129, 8281; South Island 8208.

A very common sedge on all the islands of the atoll, growing as scattered plants, never as a turf. Many of the culms on the beach ramparts and inner slope of the ramparts were dried up and apparently dead. Pure stands were frequently seen in the coconut groves along the lagoon road, at other places Fimbristylis was growing mixed with Lepturus. Around the brackish pools in the area of "caliche" soil on North Island this was the only vascular plant forming ground cover.

PALMACEAE

Cocos nucifera L. "te ni".

North Island 8373; 8411.

Distribution of coconut palms on the atoll has been discussed in describing vegetation and need not be repeated here. The coconut is certainly the staff of life of the Onotoan. It supplies him with food, toddy, shelter, rope, matting, flooring, oil and medicine. The dried product of the nut is sold to the local cooperative trading company where commodities from the outside world can be purchased.

The gathering of the "toddy" was one of the most fascinating aspects of the coconut culture. Why certain trees were selected and others disregarded for toddy collecting I never did learn. However, it was said that some trees produced more than others. Toddy trees could be spotted, since notches were cut on the lower part of the trunk. The flower buds of these trees were tied shut to keep them from opening, then the tips were cut off. The dripping sap from these cut tips was drained into a bottle or empty coconut shell by using a leaflet of coconut as a gutter. Each morning and evening the young men or boys climbed the toddy trees and replaced the

filled containers with empty ones, making a fresh cut on the bud each time. The gatherer sat on the petiole of one of the large leaves and accompanied his labor with singing. To gather toddy and not sing would cause it to spoil. It was unearthly, but beautiful to hear these voices from the tree tops at dawn and dusk. All the singers had fine voices. Usually the songs were unfamiliar, but "From the Halls of Montezuma", "Silent Night, Holy Night", "You are My Sunshine", and some other familiar tunes with Gilbertese words were also heard at these times.

The toddy is used fresh, mixed with water and is then called "karawe". If the toddy is boiled to keep it from fermenting it becomes a brown syrup and then mixed with water as a refreshing drink it is called "kamaimai". It has the flavor of coca cola that has become somewhat flat from standing. If the toddy is allowed to ferment, which requires special permission, it becomes highly intoxicating. We saw its effect upon a young man who passed out while dancing at one of the feasts. A beetle of genus *Sessinia* gets into the toddy and if not noticed and removed causes a painful inflammation of the urinary tract.

Other native names associated with the coconut are as follows:

te ben --- a ripe coconut
te riki -- a germinating coconut
te mormoto - a drinking coconut

Pritchardia sp. ?

A single plant of a fan-palm growing in front of the Government House on North Island.

ARACEAE

Cyrtosperma chamissonis (Schott.) Merr. "te babai"

North Island 8132, 8157, 8159; South Island 8211.

Extensively cultivated in pits dug in the limesand soil to a depth of 10 to 15 feet. This was the only species found in cultivation for the starch stored in the roots. Plants of all sizes, some in bloom, were found in the pits. The natives build a circular wall of coconut matting around individual plants and build up a compost, using the leaves of *Messerschmidia* and *Guettarda* mixed with darkened limesand soil from under the older trees of these species.

The land tenure of these pits was rather interesting. The families using the pits usually did not own the land in which they were dug, but permission had been granted to their ancestors several generations before. Frequently, as many as 10 different families had plantings in one pit, none of which was larger than 20x50 feet; most were smaller. The only abandoned pits seen were on the eastern side of Tabuarorae.

Since the pits were dug to a depth that would intersect the water table, algae, principally blue-greens and Rhizoclonium, covered the wet soil or grew in the shallow water. One pit had a bloom of Phacus pleuronectes in it. Mosquitoes and dragon flies bred in these pits, as indicated in the report on the animals (Moul, 1954).

AMARYLLIDACEAE

Crinum asiaticum L. "te kiepu".

North Island 8304.

Planted as an ornamental around the village houses, but not common. Also found planted in one of the cemeteries. Very few specimens were flowering during our stay on the atoll.

MUSACEAE

Musa sp.

Observed only once on the atoll: There were three trees in one of the babai pits on North Island. The plants were small and yellow green in color. In contrast, banana was common in the villages on Makin Atoll in the Northern Gilberts.

Dicotyledonae

MORACEAE

Artocarpus altilis (Park.) Fosb. "te mai".

North Island 8299.

Breadfruit trees were planted on each side of the village streets along the lagoon shore. Many of the trees were small. Young trees were planted in a circular well lined with reef rock and the roots covered with humus and dead leaves. Coconut matting was used to cover the soil, allowing the young trees to grow between the mats. Many of the trees in Aiaki village were small and poor and some of them were dead. The largest trees were in the village of Tekawa, which is located on the widest part of North Island. All the trees along the street in the village of Tabuarorae were dead. The natives reported this to be the result of the 1949-1950 drought. The fruits seen were small, wrinkled and contained large seeds.

On the island of Tabuarorae, breadfruit trees of several sizes were seen in the luxuriant vegetation along the edges of the Pisonia grove. This area was underlain with phosphate deposits, attributed to the birds nesting in the Pisonia trees. These groves were formerly more extensive and covered the area where the breadfruits were now growing.

Ficus tinctoria Forst. "te bero".

North Island 8057, 8128; Tabuarorae 8232.

Small trees were found growing on the three large islands. From their distribution it seemed apparent that most of them had been planted. These trees were growing around the edges of many of the babai pits and, in one case, in an abandoned pit. Others were planted around the houses in the villages. On North Island a row had been planted at regular intervals along a path through the coconut grove. On Tabuarorae they formed small thickets around the *Pisonia* grove. The fruits were small and used as food.

URTICACEAE

Fleurya ruderalis (Forst.) Gaud. ex Wedd. "te nekeneke".

North Island 8147, 8336; Tabuarorae 8228.

Common only at one spot on North Island, around a copra hut. Very common in many stands under the *Pisonia* trees on Tabuarorae. A native girl brought specimen 8336 to camp to trade for cigarettes. I presume these plants came from North Island.

NYCTAGINACEAE

Boerhavia diffusa L. "te wao".

North Island 8037, 8039, 8085, 8106, 8134, 8340; South Island 8198; Abanekeneke 8141.

A common plant of the seaward side of the islands, growing on both the fine and coarse coral gravel soils. Frequently found on the beach ramparts, sometimes under dead or living *Scaevola* shrubs. It was very common all over the coral gravel of the old village site on Abanekeneke. In some cases the sprawling plants spread a distance of 4 feet in all directions from the root. Both flowers and fruit were present on most plants. The flowers were pink in most cases, but a few of the plants assigned to this species had white flowers. These plants showed some intermediate characters between this and *B. tetrandra* and may be hybrids. (8141, 8198).

This and *B. tetrandra* are used as food for hogs.

B. tetrandra Forster "te waonnansi".

North Island 8084, 8151; South Island 8202; Tabuarorae 8223.

The rarer of the two species found on the atoll. Growing on coral gravels and boulder ridges of the seaward side of North and South Islands. On Tabuarorae, however, it was very common on the limesand soils in the thin coconut groves. Flowers and fruit were present on most plants. The flowers were white in this species.

Pisonia grandis R. Brown "te buka".

Aonteuma 8082; North Island 8152; Tabuarorae 8229.

Two long narrow groves of these trees about 40 feet tall were found on a ridge of indurated phosphatized limesand soil (Cloud 1952) on Tabuarorae. The only other specimens seen were a few trees on the north end of Aonteuma on coral gravel and two small groups of trees on North Island. One of these groups on the north tip of the Island grew on coral gravel and the other group was near the brackish pools on the seaward side of the island. The trees on Aonteuma and North Island had leaves badly damaged by leaf-cutting bees.

The large trees on Tabuarorae had large buttressed trunks; many would have required at least three men with arms extended to completely encircle them. The wood was very soft. The odor of ammonia was strong under these trees, due to the excrement from the large colony of nesting terns. The most luxuriant vegetation on any of the islands was on either side of these groves and consisted of *Ficus*, papaya, *Morinda citrifolia*, breadfruit saplings, with a heavy ground cover of *Fleurya* and grasses.

Bougainvillea spectabilis Willd.

The record for this plant is based on the appearance of the flowers in a "lei" worn by one of the girls on August 16th. On questioning her, it was learned that the plant grew in the yard of the house assigned to the native preacher of the village of Buariki.

Mirabilis jalapa L.

A cultivated ornamental planted around some of the houses in the village of Aiaki on South Island.

PORTULACACEAE

Portulaca lutea Solander "te mtea".

North Island 8022, 8073, 8089, 8341, 8451.

The larger leaved of the two species growing on the atoll. Great variation was noticed in the coloring of the stems of these plants, some were red.

Growing on limesand and coral gravel soils and in the groves, clearings, and on beach ramparts and their inner slope. Observed on all the islands of the atoll. In places on coral gravels it formed thick stands. The natives reported that it was used as pig food and as human food in times of famine.

Portulaca samoensis V. Poelln. "te mtea".

North Island 8023, 8072, 8107, 8284, 8395; South Island 8199.

Distribution much the same as the other species and used by the native population for the same purpose. Apparently no distinction is made by them between the species.

LAURACEAE

Cassytha filiformis L. "te ntanini".

North Island 8056, 8058, 8431.

A parasitic member of the family having a superficial resemblance to dodder (_Cuscuta_). It was found growing principally on _Scaevola sericea_ and _Guettarda speciosa_, occasionally attached to _Euphorbia chamissonis_ and _Pemphis_. One plant was found growing on _Suriana maritima_, on the island of Tabuarorae. Common along the beach rampart, rarer on the inner slope, but frequent in the sunny open areas in the center of the large islands. Widespread in the atoll wherever the host plants grew. Flowers and fruit were present during the expedition's stay on the atoll.

HERNANDIACEAE

Hernandia sonora L. "te nimaa repwurepwa".

South Island 8195.

One small tree, possibly the only one on the atoll, found along the lagoon road south of the village of Aiaki on South Island. The wood was formerly used for outriggers.

LEGUMINOSAE

Delonix regia (Boj.) Raf. "te tau".

North Island 8296.

One small tree, 6 feet tall, growing beside a house in the village of Buariki, North Island. Flowers and fruit were not present. This was the only specimen seen on the atoll.

Sophora tomentosa L. "te nikamaatuutuu".

South Island 8192; Tabuarorae 8154.

A common shrub on the narrow southern tip of South Island where the coconut trees had been killed by the drought. Growing on dune sands. The only other occurrence was on Tabuarorae as a member of the shrub community on the sand flats and bordering the inlets at the northeast end of the

island. Flowers and fruit were present on most of the shrubs.

SURIANACEAE (often included in the SIMARUBACEAE)

Suriana maritima L.

Tabuarorae 8226, 8308.

This shrub was common only on Tabuarorae. It grew on dune sand on the shore of the lagoon and as a member of the shrubby thicket on the flats at the northeast corner of the island. Fairly common as a member of the understory of the coconut groves on this part of the island. Young seedlings were present. The only other specimens seen were on the lagoon shore in the village of Buariki on North Island.

EUPHORBIACEAE

Euphorbia chamissonis Boiss. "te tarai".

North Island 8059, 8365.

This plant, with Sida fallax, formed low shrubby thickets in the center of the large islands and in many clearings in the coconut plantations. In the shade of the groves on the fine limesand soil, scattered plants of this species were frequently the only ground cover. In other groves it grew with Lepturus and Sida to form the ground cover. It was second in importance to Sida. The natives made no use of this plant.

Euphorbia prostrata Ait.

North Island 8092, 8146.

Not a common plant, but abundant where it grew. It was the dominant ground cover in the deep shade of a coconut grove at the north end of North Island. The coral gravel spread around the village houses was usually kept clear of vegetation, but in the village of Aiaki on South Island this plant was abundant in a number of these gravel yards.

Phyllanthus niruri L.

North Island 8087, 8148; Tabuarorae 8231.

Growing in the coconut groves on the three large islands, but not a common member of the ground cover. Found on lime soils and fine coral gravels. Restricted to the village areas along the lagoon. At the extreme northern end of North Island it was confined to an area of scattered copra huts. One of the common herbs found in the Pisonia groves.

SAPINDACEAE

Dodonaea viscosa (L.) Jacq. "te kaipora".

Aonteuma 8083; North Island 8303.

Found growing as a low shrub in the thin coconut grove on Aonteuma. Later, several plants were observed in the village of Buariki. Used in scenting the oil for the hair.

TILIACEAE

Triumfetta procumbens Forster "te kiaou".

North Island 8040, 8094, 8105, 8131; Tabuarorae 8234.

Fairly common on the larger islands. It was found growing on the ramparts on dune sand and was also rather common on sandy soil in the central portion of the islands. In coconut groves it frequently grew up between and over the litter scattered on the ground; some of the runners were as long as four feet. It was in flower and fruit during the period of our stay on the island.

Used medicinally by the natives for poultices and drunk as tea during child birth. Also reported used as soap.

MALVACEAE

Hibiscus rosa-sinensis L.

These plants were reported as growing in the compound of one of the native preachers, but were not located. On August 13th one of the native girls was observed with these flowers in her hair.

Hibiscus tiliaceus L. "te kiaiai".

North Island 8300, 8306, 8449.

Only two groups of these trees were found on the atoll and both were on North Island. The trees growing along the lagoon shore in the village of Buariki were the largest and were in full bloom during our visit. The other group of trees were at the south end along the road in the village of Temao. Here there was one old tree surrounded by many small ones.

The flowers, yellow with red centers, were used as ornaments in the hair of the villagers.

Sida fallax Walp. "te kaiao" and "te kaura".

North Island 8020, 8088, 8282.

One of the most widely distributed ground cover plants on the atoll,

growing at some places to a height of 2 feet. It was found on all types of soil, but was most abundant on the limesand soils under the coconut trees. Plants growing on the coral gravels were usually chlorotic. Flowers and fruit were present during the whole period of our stay on the islands. The larvae of the common butterfly, (*Hypolimnas bolina*), were abundant on the foliage.

The flowers were the favorite for making the head "leis" that everyone wore. Children following along with the collector made "leis" as they went, and the author rarely came back from an expedition without wearing one contributed by them. Sometimes the plants are used as part of the compost for the babai pits.

GUTTIFERAE

Calophyllum inophyllum L. "te itai".

North Island 8127; South Island 8203.

This tree was rare on the atoll. There were two large trees in a coconut grove on North Island. Another single tree about 25 feet tall was located east of the lagoon road at the south end of South Island. Flowers and fruit were lacking. The trees were observed in bloom on the Atoll of Majuro in the Marshall Islands on the trip to Onotoa. The lumber was formerly used in canoe building. Because of the present scarcity, it was now being used only for canoe paddles. A brown skipper butterfly was caught on the leaves of this tree and another observed flying about. These insects were observed nowhere else on the atoll and were probably specific to this plant.

CARICACEAE

Carica papaya L.

North Island 8150, 8153; Tabuarorae 8230.

Planted around a few of the houses in the villages; but not a common cultivated plant. Many small plants were found around an isolated copra hut at the north end of North Island. The largest number were growing in and around the *Pisonia* groves on Tabuarorae. The plants were in flower and fruit during our stay on the island. The natives sold us the fruit which we ate for breakfast. They were of good quality and quite good flavor.

LYTHRACEAE

Pemphis acidula Forst. "te ngea".

North Island 8036, 8050, 8086, 8315.

One of the common shrubs of the atoll, growing on sand dunes at the ends of the larger islands and on the gravel soils of the smaller ones.

In some places it formed thickets on top of the seaward ramparts. It was common also along the lagoon shore away from the villages. On North Island it formed a complete zone between the *Rhizophora* and the coconut palms at the margin of the fish ponds and also grew on the tidal flats at the upper end of the ponds. Shrubs that had grown far out on these tidal flats were now dead, probably from the higher salinity resulting from the drought of the last year and a half.

In two areas of brackish ponds, one on North Island and one on South Island, *Pemphis* formed the dominant shrub of the understory.

Flowers and fruit were present during our stay on the island. A Catocala-like moth (*Achaea janata*) was very abundant on foliage. *Cassytha filiformis* grew on *Pemphis* occasionally.

Jussiaea suffruticosa L.

South Island 8209.

Several large shrubs grew in a wet babai pit east of the village of Aiaki. These were the only specimens seen. The flowers were yellow and were present on the same shrubs with ripe seed pods.

BARRINGTONIACEAE

Barringtonia asiatica (L.) Kurz "te usi".

South Island 8205.

One small immature tree in a shallow pit on South Island, south of the village of Aiaki. The leaves were large, dark green and glossy with short red petioles. No fruit nor blossoms were observed on Onotoa. Ripe fruit were seen on Makin, Gilbert Islands, on the trip to Onotoa.

One afternoon in the Maneaba (Community house) at Aiaki, as I was passing around plant specimens in order to secure the native names, one of the group of natives told the interpreter that this tree was the only one on the atoll and was on his land. He added that the young fruit was used to poison fish and, in the old days, to poison people.

RHIZOPHORACEAE

Rhizophora mucronata Lam.

North Island 8051, 8098; Aonteuma 8077.

Confined to the north end of North Island and an embayment between it and Aonteuma. The largest stand surrounded the fish ponds and the tidal flats at the upper end of the ponds. Only two small mature trees were growing in the Aonteuma embayment, but there were many small seedlings all along the lagoon shore. The trees were in bloom and also had fruit with pendent radicles.

COMBRETACEAE

Terminalia samoensis Rech. "te ukina".

Aonteuma 8081; South Island 8191; Tabuarorae 8225.

A few widely scattered specimens of shrub size found only on the three islands listed above. They were growing on dune sand or coral gravel soils. The fruit on the Aonteuma specimens were green on July 9th. The fruit collected on South Island on July 23rd, and Tabuarorae on July 26th were scarlet. One large tree grew on the seaward rampart on South Island. The fruits were used as decorations and in making "leis". Apparently they were not eaten.

ARALIACEAE

Polyscias guilfoylei (Cogn. & March.) Bailey "te butatora".

North Island 8305.

Planted in hedges. Observed in the villages of Buariki, Taneang-Tekawa and Aiaki. The leaves were green and white and the dried plants were very fragrant.

APOCYNACEAE

Catharanthus roseus (L.) G. Don. "te buraroti".

North Island 8279.

One of the common ornamentals planted around the village houses. The white and purple flowered varieties were observed.

Nerium oleander L. "te orion".

North Island 8302.

One small shrub at a village house in Buariki. The natives knew it contained a poisonous substance.

CONVOLVULACEAE

Ipomoea tuba (Schlecht) G. Don "te ruku".

North Island 8338; South Island 8197.

This plant was found only at the two sites represented by the collections. It was most abundant on South Island near the seaward side, where it was very common and formed a dense tangle on trees, shrubs and ground. On North Island it was growing on the coral gravel soil of the rampart and was not abundant. Neither fruit nor flowers were observed.

Reportedly used as medicine to attract the girls. The common Ipomoea pes-caprae, so abundant on the island of Betio at Tarawa Atoll and on other islands visited, was missing here.

BORAGINACEAE

Messerschmidia argentea (L.f.) I. M. Johnston "te ren".

Aonteuma 8076; North Island 8156, 8279.

A common tree of the atoll, growing on all the islands except the very small ones. Frequently found in the coconut groves and a common member of the understory on Tabuarorae. It was more abundant along the seaward rampart and along the edges of the clearings. One to several of these trees always grew on the edges of the babai pits. The leaves were collected and used for compost around the babai plants. It grew on sand and gravel soils. It was in flower and fruit during our stay.

Messerschmidia was commonly infested with a caterpillar, probably the larval stage of a small Nymphalid butterfly, and also the colorful moth Utetheisa. The moth was usually at rest on the underside of the leaves.

VERBENACEAE

Lantana camara L.

This plant was not collected. It was growing around one or two village houses. It was used by the girls as hair decoration.

Clerodendrum inerme (L.) Gaertn. "te inato".

Aonteuma 8080; North Island 8298.

Small shrubs which tended to be vine-like, were growing on Aonteuma. They were in thickets of Guettarda and Scaevola and under the coconuts. The soil here was coral gravel. Neither flowers nor fruit were present.

They were also found around some of the houses in the village of Buariki. The flowers were used in making "leis".

Premna obtusifolia R. Br. "te aango".

Aonteuma 8078; South Island 8194, 8196.

A common shrub of the south end of Aonteuma, growing on coral gravel soil. The only other occurrence was on the lagoon shore of South Island, south of the village of Aiaki. Here some of the shrubs grew to a height of fifteen feet. Flowers and fruit were present during our stay on the atoll. Premna was reported to be used as a medicine. Some of the leaves showed damage by leaf-cutting bees.

SOLANACEAE

Physalis lanceifolia Nees

North Island 8093, 8149.

A few plants growing beside a copra shack at the northern end of North Island. No other specimens seen, both collections being made at the same site. Flowers and fruit were present.

SCROPHULARIACEAE

Russelia equisetiformis Schlecht & Cham. "te kaibaun".

North Island 8167, 8307, 8387.

A common plant around the Residency and the village homes.

Collections were made only on North Island, but the plant was present on South Island and Tabuarorae. The scarlet flowers were highly prized for "leis".

ACANTHACEAE

Pseuderanthemum carruthersii Seem. "te roti".

North Island 8038, 8301.

Commonly cultivated and growing around the houses in all the villages. In the cemeteries at the northern and southern tips of North Island, a number of graves had these shrubs growing at one end. Two varieties were observed. One variety had purplish-green leaves, dark twigs and magenta flowers. The other variety had green leaves and light colored twigs. No flowers were observed on the latter.

RUBIACEAE

Guettarda speciosa L. "te uri".

North Island 8041, 8280, 8333; Aonteuma 8079.

Second in importance to Scaevola as an understory tree and thicket former. It was found on all types of soils on all the islands, including the very small coral gravel islands between North and South Islands. Flowers and fruit were present during the time we were on the atoll. It was frequently parasitized by Cassytha filiformis.

The fragrant flowers were used by the natives for "leis". The women spread a dozen or so leaves on the ground on which to dry the pandanus pulp. The skin from the fruit of this plant, with a part of the root of Scaevola, were said to be used to cure venereal disease. These were crushed

together, the juice put into a drinking coconut and this mixture drunk by the patient. One treatment is said to be effective.

Morinda citrifolia L. "te non".

Abanekeneke 8104, 8140; Tabuarorae 8227.

This plant was found growing principally below the ramparts on the seaward side of the islands. Also a member of the Pisonia grove community. It most frequently grew on coral gravel soils. Signs of damage by salt spray were evident on the small island of Nanntabuariki. The trees on North Island had been attacked by the leaf-cutting bees. A large Sphingid caterpillar, larva of the day-flying hawk moth, was found on the foliage of the trees in the cemetery on North Island. The tree was also planted around the houses in the villages. Both flowers and fruit were present during our stay on the island. The fruit is used as food in times of famine, but apparently not highly regarded or used at other times.

GOODENIACEAE

Scaevola sericea Jahl "te mao".

North Island 8024, 8283, 8396.

The commonest understory and thicket former on the atoll. It was present on all the islands and grew on all types of soil. It formed dense thickets in the neglected coconut groves. On the seaward ramparts it formed solid thickets at many places and these plants showed a considerable amount of killing by salt spray. New shoots, however, arise directly from the root stock. It was in flower and fruit during the time we were on the atoll and was frequently parasitized by Cassytha filiformis.

COMPOSITAE

Vernonia cinerea (L.) Less. "te waonnansi"

South Island 8193.

This small composite was found growing along the lagoon road both north and south of the village of Aiaki, South Island. It was fairly common in this area, but not found at any other location on the atoll. The flowers were light purple.

PTERIDOPHYTA

No members of this group of plants grew on Onotoa.

Polypodium scolependria was common on Majuro Atoll, Marshall Islands. IX/5/51.

BRYOPHYTA

The mosses and liverworts collected on the expedition to Onotoa were determined by Dr. H. A. Miller and samples retained in his collection. Duplicate specimens were distributed to the Herbaria indicated above.

Because of the irregular amount of rainfall on Onotoa, with long periods of drought, Bryophytes were not common on the atoll. Mosses grew on the lime-sand soil along roads and paths and on soil bare of vascular plants. The heaviest growth was in the shade of trees. Most of the moss patches were surrounded by a thick growth of terrestrial blue-green algae. Black tufts of Scytonema ocellatum frequently were mixed with the moss plants and suggested the presence of another species. Only one species of moss was found and no liverworts were collected on Onotoa. Dixon (1927: Jour. Bot. 65:254.) has previously recorded Brachymenium indicum (Doz. & Mott.) Bry. Jav. as occurring on Onotoa, but this species did not show up in the collections. Miller indicates the one species found to be Brachymenium melanothecium (C. Müll.) Jaeg. and states that it is widespread in Oceania. The following collections were made:

North Island 8060, 8061, 8095, 8176.
South Island 8213.
Tabuarorae 8241.

On the trip out to Onotoa from Kwajalein Atoll, there were opportunities to collect on the various atolls visited. These collections are included below.

MUSCI

Calymperes tenerum C. Müll.

Majuro Atoll, Marshall Islands.

8002. Growing on the trunk of a palm tree in a shaded area, Rogeron Island, VI/18/51.
8621. Growing on a breadfruit tree, Rogeron Island. VI/18/51.

Kwajalein Atoll, Marshall Islands.

8001. Base of palm tree. Kwadak Island. Species widespread in Oceania. (Miller, 1953, p. 5).

Calymperes thyridioides Broth.

Majuro Atoll, Marshall Islands.

8005. On rotten wood in a Scaevola thickets. Uligak Island. VI/19/51.
Previously reported from Arno Atoll and other places in the Marshalls as C. moluccense by Miller, 1953, p. 4. (Miller personal correspondence).

HEPATICAE

Archilejeunea mariana (Gott.) St.

Kwajalein Atoll, Marshall Islands.

8000. On the bark of Pisonia trees. Fairly common on the horizontal branches. Wooded center of Kwadak Island. VI/17/51.

According to Miller (Correspondence) this is a rather depauperate specimen but falls within the range of the species. Widespread in Oceania.

Hygrolejeunea vesicata (Mitt.) Stephani

Majuro Atoll, Marshall Islands.

8003. On the trunk of a palm tree. Rogeron Island. VI/18/51.
Miller states (Correspondence) that he believes this species belongs in Cheilolejeunea. The material from the Marshalls is slightly smaller than the type.

LICHENES

The few lichens found have been turned over to Dr. George A. Llano, Maxwell Field, Alabama, for determination. These collections were made in dense thickets on the bark of Guettarda, Morinda, Pandanus and coconut trees.

FUNGI

The fungus collections made on Onotoa have been turned over to Dr. Donald P. Rogers at the New York Botanical Garden and determinations have not been made at this date.

A number of species of bracket fungi were collected on rotting logs. The commonest was a red polypore. A reticulate orange slime mold was found on decaying pandanus leaves. A white gilled fungus was collected several times from the base of living coconut palms. Fungus beetles were present in some of the specimens collected.

Soil Flora

Samples of soil were collected on the atoll and brought back to the Department of Microbiology at Rutgers University. The analysis of the flora of these soils was made through the kindness of Dr. R. L. Starkey and Dr. Hubert A. Lechevalier. I quote from Dr. Starkey's report:

"These represent determinations for numbers of bacteria and actinomycetes determined by the customary agar plate procedures.

Sample No.	pH	Numbers of microorganisms, per gram of soil		
		Bacteria	Actinomycetes	%Actinomycetes
8335	8.0	328,000	4,957,000	94
8243	8.4	200,000	3,982,000	95
8332	8.0	971,000	2,100,000	68
8120	8.0	1,705,000	6,140,000	82

It is to be noted that the reaction of all soils was distinctly alkaline. Of particular interest is the fact that the numbers of bacteria were in all cases lower than those of actinomycetes and that with 3 of the 4 soils more than 80 per cent of the colonies that developed on the agar plates were those of actinomycetes. A similar observation was made with soil obtained some years ago from Bikini. This is contrary to what one expects to find in soils of temperate regions particularly those of humid climates. These soils are generally acid (pH 6.0 or less) and the percentage of the total colonies that are produced by actinomycetes generally vary between 5 and 40 per cent.

The predominance of actinomycetes is interesting in view of the fact that many of these organisms produce antibiotics. It is possible, therefore, that the actinomycetes affect the transformations of material in the soils by their antagonistic effects. It is also possible that some actinomycetes may be obtained from these soils that will serve some useful purpose as producers of new chemotherapeutic substances."

Sources of the Soils

8120. Lime sand soil from the center of North Island.
8243. Lime sand soil from Tabuarorae under vegetation.
8332. Soil from babai pit. North Island.
8335. Soil from under *Guettarda* tree, south end of North Island.

ALGAE

Taxonomy and Distribution of Algae

The algae from Onotoa include both fresh-water and marine forms. The fresh-water habitats include the soil surface, the babai pits and the brackish pools. The marine habitats include the beach rock, lagoon and the seaward (windward) reef. Many of the lagoon collections were made by Dr. Preston E. Cloud, Jr., Dr. Donald W. Strasburg and Dr. A. H. Banner while carrying out their own explorations. The identification of the algae is still in preliminary stages and much material remains to be determined. The identification of the Myxophyta to species has been done by Dr. Francis Drouet at the Chicago Museum of Natural History and specimens are deposited there. As identification proceeds complete sets of all algae are being deposited in the U. S. National Herbarium, Bernice P. Bishop Museum, and the Chrysler Herbarium at Rutgers University. Duplicates have been distributed to the New York Botanical Garden, University of California Herbarium at Berkeley, University of Michigan Herbarium, Farlow Herbarium at Harvard and the Herbarium of the University of Sao Paulo, Brazil.

The following report includes a limited and preliminary discussion of the ecology of the algae on the atoll, followed by a species list of the algae identified to date. It is the hope of the author to publish a detailed final report on the algae at a future date. A paper on the *Halimeda* and *Caulerpa* of the atoll is already in manuscript form and will be submitted for publication shortly.

Algae of the soil surface.

The surface of the road that parallels the lagoon from North Island to Tabuarorae was covered by a "skin" of blue-green algae. This was also true of the well-worn paths and the soil where it was bare of vascular plants and remained undisturbed. Two species of *Schizothrix* and *Scytonema hofmannii* were very common and formed the bulk of this association. Other blue-greens occurred with these principal species. Some black moss-like tufts growing around areas occupied by mosses proved to be *Scytonema ocellatum*. The dune sands of the seaward rampart and the lagoon shore had *Microcoleus chthonoplastes* and *Scytonema hofmannii* as the dominant algae. It is interesting to note that this species of *Microcoleus* is the dominant alga covering the peat surface on the salt marshes of New Jersey. These terrestrial blue-greens were present as a soil covering on the bare areas all over the atoll, both in sun and shade.

It has been established that many of the blue-greens, especially those belonging to the Nostocales, can fix nitrogen. The presence on the soil of vast sheets comprising many species suspected of having this ability may be very significant in the productivity of the soil. This is probably an important method by which this element is made available to higher plants (Newhouse, 1954, p. 53). The holding of soil against wind erosion is another important contribution of this group of plants.

Algae of the babai pits.

The native taro, called babai (Cyrtosperma chamissonis), is grown in pits dug to the water table. The amount of water present in the pits varied from 6 inches of standing water to just enough to dampen the soil. In all the pits thick mats or scums were present. Collections of these scums were made in many of the pits, and the algal flora showed considerable variation. In some, Rhizoclonium hieroglyphicum was dominant. In others, members of the blue-green algae, such as Anacystis dimidiata, Plectonema nostocorum and Coccochloris stagnina, were dominant. One pit sampled had as the dominant form Phacus pleuronectes; associated with it were members of the genus Euglena.

Here again members of the Myxophyta were probably contributing available nitrogen compounds to the soil and thus to the growing babai plants. The algae here were the primary producers in the food chain that supported the protozoa, rotifers, nematodes, ostracods, and eventually the dipterous larvae and dragonfly nymphs present in these pits.

One of the fresh-water wells used by the natives in the Government Area on North Island was found to have a mat of Rhizoclonium hieroglyphicum floating on the water surface. The water level in the well was approximately 8 feet below the surface of the soil. The opening of the well was between 3 and 4 feet in diameter which admitted sufficient light for growth.

Algae of the brackish pools.

In the area of caliche soil on the Pemphis flats at the north end of North Island there were a number of brackish pools (Cloud: 1952. Atoll Res. Bull. 12:60). These pools were covered by a floating, orange-colored gelatinous mat. The shaded portions and the under surface of the mat were olive-green in color. Two species of Anacystis were the dominant algae, with Coccochloris stagnina and three species of Lyngbya also present. The bottoms of these pools were lined with a more granular and warty mat. The same species were present, but the Lyngbya species were more abundant. A similar association for brackish pools has been reported by Newhouse (1954, p. 42). The same association of living organisms described above for the babai pits was present in these pools.

MARINE HABITATS

The distribution of the marine algae is best discussed under the two major marine habitats, the lagoon and the seaward (windward) reef. There are beach rock associations in both areas that have somewhat different associations of algae present.

A complete description of the geology and topography of the lagoon has been published by Cloud (1952, p. 18). Algal growth in the lagoon as a whole was relatively sparse. The areas of the lagoon are described below with an account of the principal algal species present.

Beach rock of the lagoon.

At a number of places along the shore of North Island there were outcroppings of beach rock. Near the village of Taneang a long ridge extended out from the beach at an angle of 45°. Collections of algae made from the surface of these rocks showed two species of Entophysalis as dominant, with Calothrix pilosa and Nostoc muscorum also present. These species proved to be present on beach rock at other places on the lagoon shore. Newhouse (1954, p. 45) reports this association as the most ubiquitous on Raroia, from high tide line to below low tide on the lagoon shore. He also reports the dark coloration on the surface of the rocks due to discoloration of sheath material of Entophysalis by exposure to sunlight. This dark discoloration was also evident on Onotoa.

Shoreward from the ridge and sheltered by it, the lime-sand bottom had become hardened to the consistency of hard putty and had the same blue-green algae on the surface as listed above; however, at about one fourth inch depth was a second layer of blue-greens which consisted of Oscillatoria nigro-viridis, Lyngbya confervoides and Phormidium valderianum. It is proposed by Cloud (1954) and others that these blue-greens are binding the lime silt into beach rock. This same type of double-layered association was present at other places along the lagoon shore.

Frequently the beach rock had been eroded and shallow oval tide pools formed at different levels. These solution pools have been studied by Cloud (1954). They were filled with water by the high tide and the shallow bottoms were covered with algal growth. A solid mat of an alga tentatively identified as Enteromorpha compressa grew in these pools. Other collections from the pools are awaiting determinations.

Lime-sand shoals.

The central lagoon along the shore of North Island had a fine lime sand bottom, populated by great numbers of sea cucumbers. Microdictyon and Bryopsis pennata were collected in the wash along the beach. Because of the shoal condition it is possible to wade and swim out into the lagoon about a 1000 feet. The algae were sparse on this shallow flat. Patches of a filamentous, gray colored species have been determined as Lyngbya confervoides. It grew on the sandy bottom, and as it proliferated it tended to accumulate mounds of the fine silt with only the ends of the filaments protruding. Farther out were small patches of Turbinaria ornata with Microdictyon growing with it. Caulerpa urvilliana was collected on rock fragments beyond the end of the jetty. The pebbles in this area were covered with pink coralline growth.

Thalassia beds

North of the jetty on these sand flats there were large patches of Thalassia hemprichii that formed an almost solid stand. Attached to these plants and floating free among them was a species of Microdictyon.

Hydrocoleum floccosum was common along the shoreward edge of these beds. Caulerpa serrulata and Halimeda stuposa were present in the sandy areas between the Thalassia plants.

Northern lagoon.

Between the Thalassia beds and Aonteuma Island was a gravelly flat on which grew some living coral. At low tide these flats were covered by only about a foot of water, so the coral masses in many cases were truncated. The algae here were growing in sand pockets scattered between the masses of dead and living coral. Halimeda stuposa was the common alga here. Many of the specimens had developed thick heavy stipes that penetrated deeply into the sandy substrate. Lyngbya confervoides formed mounds of silt as described above. Dictyosphaeria intermedia, Boodlea van bossae and Caulerpa urvilliana were other common algae present. Laurencia grew on some of the coral knobs.

These same species were present on the shallow reef flat northeast of Aonteuma, but there was an increase in the number of Halimeda plants, including another species, Halimeda taenicola. Turbinaria ornata and Dictyurus purpurascens were also found here. Laurencia grew in the tide pools. A crustose coralline alga covered the surface of this reef in many places.

Western lagoon and reef.

The greatest concentration of algae species in the lagoon was on the western (leeward) reef and the coral knolls in the western part of the lagoon. Most of the Halimeda species found on the atoll were collected either on the reef or on the coral knolls. Many of these knolls were surrounded at their bases with a circle of Halimeda, but these did not form extensive meadows over the bottom as one sees in Florida. Caulerpa elongata, C. urvilliana, Dictyosphaeria cavernosa and Valonia aegagrophila were common in this area. Polysiphonia and Dasya were epiphytic on other algae. Coralline algae (Porolithon) formed huge spherical masses on the coral knolls, and crustose forms were covering the dead coral.

The deepest part of the lagoon was west of the village of Aiaki, South Island. Here on a bottom of dead and living coral at 48 feet grew Halimeda bikinensis and H. tridens forma tripartita.

Passage and Central lagoon reef.

Between North Island and Abenekeneke Island was a passage covered with flowing water even at low tide. Most of the bottom was fine sand, but on the occasional dead and living coral grew Caulerpa urvilliana, Laurencia and many fine red algae. Frequently the rhizoidal process of the Caulerpa would grow off the coral and trail across the sandy bottom.

A shallow reef flat adjacent to the passage and extending into the lagoon at the southern tip of North Island was dry at low tide, except for the tide pools. Cladophoropsis, Dictyosphaeria, Valonia, Caulerpa urvilliana and Enteromorpha were growing on this reef. In the tide pools, Lyngbya confervoides grew and accumulated mounds of silt as observed before. Laurencia and Goniolithon also grew in the tide pools. The algal cover on this reef was sparse.

The seaward reef.

The seaward (windward) reef flat was covered by a fine algal turf. The distribution of the algae on this reef was studied by observations and collections made from time to time during July and August. After Dr. A. H. Banner had established a transect (A) to study the invertebrate fauna, one square foot of algal turf was scraped from the reef along this transect and preserved. These collections were made at 50 foot intervals, except where the flora showed no perceptible change. The accompanying table (1) shows the distribution of the principal species as determined at this time.

This reef can be divided roughly into five areas. Starting at the vegetation line on the beach rampart there is a sloping sandy beach or an outcropping of beach rock. On the sand at the high tide line there was usually a drift deposited after each high tide which included shells, seeds, plant fragments and algae of the reef.

The beach rock here had the same dark gray color on the surface as that present in the lagoon, the color being due to the presence of species of Entophysalis. The upper tide pools were 5 to 6 feet above the reef flat and were filled with water only from the splash of waves at high tide. They had a slimy black coating on the bottom formed by a species of Lyngbya. The slime coating was thin in these top pools and it was necessary to scrape vigorously to collect it. The middle pools were $3\frac{1}{2}$ to 2 feet lower and contained a mat of twisted yellowish or brownish filaments. Entophysalis conferta, Lyngbya confervoides, L. semiplena (8064, 8067) and Enteromorpha (8066) were the principal species in these pools. Naviculoid diatoms were also present. Water entered these pools from the waves at high tide. Lyngbya meneghiniana (8350) was the alga of the bottom pools along with L. semiplena; this last was common on the reef at the beach line. Oxyrrhis marina, a pigmented dinoflagellate, and naviculoid diatoms were present among the filaments.

The inner zone of the reef flat itself looked barren and when dry was the color of the sand. Closer inspection showed a solid turf of a fine red alga almost completely covered with fine silt. Green algae grew around the edges of the pools shaded by the overhanging sides and on the underside of stones in the pools. The bottoms of many of these pools were usually scoured clean of algal growth. This type of reef extended to about the 250 foot quadrat.

The second zone of the reef had a predominantly green aspect from a distance and started roughly at the 300 foot quadrat. At low tide this part of the reef showed an almost continuous series of tide pools and standing water. Considerably more water was present here at low tide than on the reef at either side. Dictyosphaeria and Cladophoropsis were the common algae present, covering the flat itself and showing the darkest green around the edges of the pools and under the shaded overhang of projections. Jania capillacea made its appearance in this zone. Much fine silt was caught in the algal turf. The outer border of this reef zone merged with the next zone between 450 and 500 feet.

The third zone was red in color and extended to the coralline ridge at 600 feet. It was covered almost continuously with Jania decussato-dichotoma. The Jania cover became heavier in the back-ridge trough which was filled with water continuously. Fleshy gelatinous red algae grew at the base of the Jania. Very few green algae were present, usually only Dictyosphaeria. A branched coralline alga, Goniolithon, occurred in the wider parts of this zone and sometimes formed solid stands. The outer edge of this zone was irregularly defined by the surge channels and mounds that extended back from the ridge itself.

The coralline ridge formed the outermost zone and was continually washed and battered by the heavy surf. This ridge was most spectacular in appearance, extending in each direction as far as the eye could see. Setchell (1924: Veg. of Rose Atoll, Car. Inst. Pub 341:243) quotes the Funafuti report in which this spectacular Onotoan reef was described. The same species that form the reef here at Onotoa, occur on Rose Atoll.

The ridge front was covered completely with a smooth pink crustose coralline alga, probably Porolithon onkodes. The ridge was broken by long, smooth-walled surge channels, 4 to 5 feet deep and gradually becoming shallower, ending in the back ridge trough. Each wave hitting the front of the ridge sent a rush of water up these surge channels into the back ridge trough. Alternating with the surge channels were dividing mounds 3 to 4 feet higher than the general elevation of the reef. These mounds were covered by upright pinnacles of Porolithon craspedium f. mayorii, pink in color, but fading to white on drying. Jania covered the base of the ridge as a short turf and also grew around the bases and between the blade-like projections of the Porolithon craspedium. Caulerpa urvilliana occasionally grew on the slope of these mounds. Very few of the cushiony greens occurred here. Dictyosphaeria setchellii grew along the surge channels. On the smooth shaded walls of the channels Rhipilia orientalis was inconspicuous, but common. Here is another example of the distribution mentioned by Doty (1954, p. 367) where the genus Rhipilia occurs on an atoll in the absence of the genus Sargassum.

Records for the square foot quadrats.

1. Beach line. (8123). Algal felt was scanty and short, giving barely any color to the reef surface. The bottoms of the pools at this level

were scoured clean. The dominant algal forms were small soft tufts with much sand intermingled, and these were identified as Schizothrix cresswellii and Lyngbya semiplena. A prolific branched species of Enteromorpha was fairly common.

2. Transect at 50 feet. (8124). A reddish color was observed on the reef flat here and the turf was more or less continuous. An alga tentatively identified as Pterocladia formed this reddish turf which was 8 to 10 mm. tall. Only the ends of the filaments protruded from the fine silt. Dictyosphaeria and Cladophoropsis, the green algae present, grew around the edges of tide pools. Small amounts of Jania capillacea grew in the cushions of the green algae. A Chroococcus-like blue-green alga formed dense mats around other algae.

3. Transect at 100 feet. (8125). The flora was much the same as described for the 50 foot transect. The growth of Pterocladia and the green algae bordering the tide pools was heavier. Porolithon onkodes encrusted pebbles in the tide pools.

4. Transect at 150 feet. (8126). Pterocladia was still present giving a reddish color to the reef flat. Cladophoropsis and Dictyosphaeria grew into huge cushions forming a solid ring around tide pools. Lyngbya sordida grew along the edges of these pools. Jania was growing mixed with Cladophoropsis.

5. Transect at 200 feet. (8136). Traces of Pterocladia were still present on the reef flat, but Cladophoropsis was dominant, extending out over the reef flat from the edges of the tide pools. Other species present as described in 150 foot transect.

6. No sample at 250 feet.

7. Transect at 300 feet. (8137). Species of green algae, Cladophoropsis, Boodlea and Dictyosphaeria completely encircled the pools and covered most of the reef flat. Red algae were very scarce at this station on the reef. Porolithon pebbles were present in the tide pools.

8. Transect at 350 feet. (8163). The turf covering the reef here was very short. Water covered most of this section of the reef at low tide. In addition to the species present at 300 feet, Jania capillacea was the dominant red alga present and grew over and mixed with Boodlea.

9. No sample at 400 feet.

10. Transect at 450 feet. (8164). The general aspect of the reef was still green at this station. The reef flat was dry here at low tide, but there were many tide pools filled with water. Green species were present as above. Laurencia, bleached yellow, was common in the tide pools. Crustose corallines were more common. Two species of Jania were abundant, with J. decussato-dichotoma the common species. An occasional specimen of Porolithon gardineri was found in this area.

11. Transect at 500 feet. (8168). The predominant color of the reef from this point to the surf line was red. Jania decussato-dichotoma was the dominant alga here on the reef flat. Laurencia was also common. Boodlea, Cladophoropsis and Dictyosphaeria grew around the edges and in the bottom of the tide pools.

12. Transect at 550 feet. (8169). Jania decussato-dichotoma had almost 100% cover at this station. A large species of Laurencia was present and a few small plants of Dictyosphaeria. Centroceras clavulatum was growing on the Laurencia. Goniolithon frutescens first appeared on the reef at this point.

13. Transect at 600 feet. (8170). The back ridge trough started at this quadrat. The reef flat was almost completely covered with an entangled growth of Jania and the branching coralline Goniolithon. The Laurencia growing here was frequently covered with epiphytic diatoms Licmophora and Cocconeis.

14. Transect at 650 feet. The coralline ridge constituted the outer zone of the reef and has been described above.

Table 1. Distribution of algae on the seaward (windward) reef.

Algae	Beach	50	100	150	200	300	350	450	500	550	600	650
		Distance from beach (feet)										
Lyngbya semiplena	D	t										
Schizothrix creswellii	D											
Enteromorpha sp.	D											
Cladophoropsis sp.		P	P	P	D	D	P	P	t			
Dictyosphaeria spp.		P	P	t		D	P	P	P	P	t	t
Pterocladia sp.		D	D	D	t	t				t		
Jania capillacea		t	t	P	P		D	P				
Porolithon onkodes			P	P	P	P	P		P	P	P	P
Lyngbya sordida				P								
Laurencia spp.				t					D	D	D	
Boodlea sp.						t	P	P	P			
Jania decussato-dichotoma							P	D	D	D	D	P
Porolithon gardineri								P				
Goniolithon frutescens										P	P	
Porolithon craspedium												D
Caulerpa urvilliana												P
Rhipilia orientalis												P
Polysiphonia sp.									t	t	t	t

Key: D-dominant species. P-present in fair quantity. t-traces only.

ALGAE

Tentative Species List

Myxophyta

Identification to species in this group were made by Dr. Francis Drouet, Chicago Museum of Natural History.

Anabaena sp.

North Island 8325.

A few filaments were found growing in a mat of Rhizoclonium hieroglyphicum on the sandy surface of a babai pit.

Anacystis dimidiata (Kütz.) Dr. & Daily

North Island 8166, 8345, 8346.

A member of the algal flora in the babai pits around the base of the Eleocharis plants. This species was also found in the thick mat on the surface of the brackish pools in the "caliche" soil area. This mat was orange in color on top, but olive-green below. It was also present in the granular bottom scum of these same pools. Other algae present in these mats were A. montana, Coccochloris stagnina, Lyngbya versicolor, L. aestuarii, L. guaymensis.

Anacystis montana (Lightf.) Dr. & Daily

North Island 8345, 8103; South Island 8216, 8217. Tabuarorae 8236.

This species was present as part of the flora in the mat on the surface of the brackish pools. It also occurred with Scytonema hofmannii on bare sandy areas between large coral fragments on the exposed northern tip of North Island. Blue green algae collected from coconut and Pandanus logs also contained this species associated with S. hofmannii.

Calothrix pilosa Harv.

Lagoon beach 8182, 8393.

A spongy mass on the beach and on beach rock at the high tide line; the collections were made at the north end of the lagoon near the village of Teneang. Growing here with other blue greens.

Coccochloris stagnina Spreng.

North Island 8324, 8345, 8346; Tabuarorae 8242.

One of the species common in the flora at the bottom of the babai pits, in one case associated with Plectonema nostocorum. This species was also found as a member of the floating mat described under Anacystis dimidiata.

Entophysalis conferta (Kütz.) Dr. & Daily

North Island 8064

Growing in the middle tide pools of the beach rock outcrop on the seaward side of the North Island at the camp site. These are the tide pools studied in respect to their pH and temperature, as reported by Cloud (Atoll Res. Bull. #12, 1952). This species also covered the beach rock and gave it a bluish color, (see Newhouse, 1954. Atoll Research Bull. #33: 53). Other species present in the tide pool were Lyngbya confervoides and L. semiplena.

Entophysalis crustacea (J. Ag.) Dr. & Daily

North Island 8182.

Found covering the beach rock at high tide level in the lagoon near the village of Teneang. Associated with Calothrix pilosa and other blue greens.

Entophysalis deusta (Menegh.) Dr. & Daily

North Island 8183.

Growing on beach rock at high tide level, 100 feet from shore. Same area as E. crustacea.

Fischerella ambigua (Nag.) Gom.

North Island 8144.

Found on the soil at the top edge of a babai pit. Associated with Scytonema hofmannii.

Hydrocoleum floccosum (Hauck.) Gom.

Lagoon 8190.

Growing on the bottom of the lagoon and covered at low tide. Common at the shore end of the Thalassia beds (turtle grass).

Lyngbya aestuarii Gom.

North Island 8119.

A member of the community of algae in the scum on the brackish pools. See Anacystis.

Lyngbya confervoides Ag.

Lagoon 8026, 8028, 8182; North Island 8064.

Growing on the lagoon reef flat at the south tip of North Island, at low tide level about 100 feet from shore. The fur of filaments had become filled with fine lime silt, so that only the tips showed above the loose mass. This condition was noticed at other places over the lagoon bottom. This species was also a member of the flora in the middle tide pools of the beach rock on the seaward side of North Island. It was found associated with Entophysalis crustacea on beach rock in the lagoon. At one site this species formed a dark blue green stratum about ¼ of an inch below the surface of the soft beach rock.

Lyngbya guaymensis Dr.

North Island 8119, 8345.

A member of the floating mat community in the brackish pools. See description under Anacystis dimidiata.

Lyngbya meneghiniana (Kütz.) Gom.

North Island 8350.

A member of the flora growing in the lowest tide pools in the beach rock on the seaward side of North Island.

Lyngbya semiplena Gom.

North Island 8064, 8067; seaward reef 8123.

A member of the algal community from the middle tide pools of the beach rock on the seaward side of North Island. With Entophysalis conferta and Lyngbya confervoides. In the first of a series of transects scraped from the seaward reef, this species with Schizothrix cresswellii were members of the algal felt covering the reef at beach level.

Lyngbya sordida (Zanard.) Gom.

Seaward reef 8390C, 8482C.

This plant was present in the tide pools of the green algal zone of the seaward reef, associated with Dictyosphaeria.

Lyngbya versicolor Gom.

North Island 8119, 8345, 8346.

This species was growing in the floating mat community and in the granular bottom deposits in the brackish pools of the "caliche" area. See under Anacystis dimidiata.

Merismopedia sp.

North Island 8166.

In the material collected from the babai pits a few specimens of this genus were found.

Microcoleus chthonoplastes (Fl. Dan.) Thur.

North Island 8134, 8473; lagoon 8180.

One of the algae present in the soil community of the old dune sands of the rampart on the seaward side of North Island. Growing with Scytonema hofmannii. It was also found on the lagoon beach.

Nostoc muscorum Ag.

Lagoon 8179.

Occurring on exposed, incipient beach rock of the lagoon at low tide level, with Scytonema hofmannii.

Nostoc sp.

North Island 8320, 8322.

Young material was growing on the soil of a path in the center of North Island in a community including Schizothrix heufleri and Scytonema hofmannii. Drouet reports that the material in 8322, which was associated with a moss, was parasitized.

Oscillatoria nigro-viridis (Thur.) Gom.

Lagoon 8182B.

This species formed a light green stratum in beach rock at high tide level in the lagoon at the profile studied at the village of Taneang, North Island. Here it was associated with Lyngbya, Calothrix and Phormidium valderiarnum.

Phormidium crosbyanum Tild.

Bikati Island, Big Makin Atoll, Gilbert Islands 8009.

This species covered the coral rocks and lined the depressions on the reef at high tide level.

Phormidium valderiarnum Gom.

Lagoon 8182B.

Associated with Oscillatoria nigro-viridis which see.

Plectonema nostocorum Gom.

Tabuarorae 8242.

This alga was present in the mat in the bottom of an abandoned babai pit, growing with Coccochloris stagnina around the stems of Eleocharis.

Schizothrix cresswellii Haw.

Seaward reef 8123.

With Lyngbya semiplena, growing in the first transect of algae scraped from the seaward reef at beach level.

Schizothrix friesii (Ag.) Gom.

North Island 8111, 8285, 8321; Tabuarorae 8240.

Covering the soil (silty loam) on paths, in the sun as well as in the shade. It was also collected on the beach rampart. Most frequently it was associated with Scytonema hofmannii.

Schizothrix heufleri Grun.

North Island 8320.

The skin-like coating on the soil surface of a path in the center of North Island was formed by this alga and two associates, Scytonema hofmannii and young Nostoc.

Scytonema guyanense (Mont.) Born. & Flah.

North Island 8118.

This species was growing on the roots of a fallen coconut tree.

Scytonema hofmannii Ag.

North Island 8103, 8134, 8144, 8160, 8285, 8321, 8322, 8473; lagoon 8179; South Island 8215, 8217; Tabuarorae 8236.

The common blue green alga of the soil community, it was found growing on the paths, roads, seaward rampart and logs. It also occurred in the babai pits. Only one collection was found on the beach rocks in the lagoon, where it was associated with Nostoc muscorum. In the soil collection it grew with a wide variety of blue greens including the following genera: Anacystis, Fischerella, Microcoleus, Nostoc and Schizothrix.

Scytonema ocellatum Lyngby

North Island 8096; Tabuarorae 8241B.

The black tufts of this alga resembled the moss plants with which it grew. It was found on lime sand soil along the lagoon road, usually in deep shade.

Chlorophyta

Avrainvillea sp.

Western Reef 8443.

This is probably *A. nigricans* Dec. but final determination has not been made. Growing in 5 feet of water attached to coral rocks. The plant was 4½ cm tall.

Boodlea sp.

Seaward reef 8137, 8163.

Scattered plants of this unidentified *Boodlea* grew on the seaward reef. This area was dry at low tide except for the tide pools which were usually clear of algae. In the preliminary survey of the algal felt scraped from the seaward reef this specie was found sparingly in the 300-foot transect along with other green algae, but in the 350-foot transect it formed a turf overgrown with *Jania capillacea*.

Boodlea vanbosseae Reinbold.

Lagoon 8421.

This species grew on the flats at the northwest corner of the atoll and was exposed at low tide. It was growing with *Ceramium* and *Polysiphonia*.

Bryopsis pennata Lam.

Lagoon 8354.

The only specimen of this plant that has been found in the collections so far was a thick mat washed up on the lagoon beach.

Caulerpa elongata Weber Van Bosse.

Lagoon 8260, 8261, 8263, 8401, 8452.

This species of *Caulerpa* was confined to the western side of the lagoon. All but one specimen were attached tightly to coral rocks. The exception was found growing on *Valonia aegagrophila*, which was attached to coral rock. Both f. *typica* and f. *disticha* were recorded. Because of its

small size this species may have been overlooked frequently.

Caulerpa serrulata (Forssk.) J. Ag.

Lagoon 8052, 8425; Betio, Tarawa Atoll 8624.

The specimens assigned to this species were confined to shallow water in the central part of the Onotoa lagoon on lime sand bottom. It also grew in the Thalassia patches of the north central lagoon. The Tarawa specimen was collected on the western seaward reef of Betio.

Caulerpa urvilliana Mont.

Lagoon 8029, 8052, 8249, 8235A, 8317, 8408, 8409, 8425, 8433.
West reef at Aonteuma 8100; flat, east of Aonteuma 8423.
Water-way between islands 8143, 8445; seaward reef 8174, 8188.

The commonest species of Caulerpa on the atoll. It grew in shallow waters, uncovered at low tide, down to a depth of 14 feet. It was present in the patches of Thalassia in the lagoon. The isolated patches of coral in the flowing water between the islands had growths of this Caulerpa on them. It was attached by the root-like structures of the horizontal rhizoid to coral rock, lime sand, living blue coral and the coralline algae crust of the seaward ridge. Wherever it grew the habit of the plant tended to cause the deposition of silt. Microdictyon and many small red algae grew upon it as epiphytes.

Chaetomorpha sp.

Lagoon 8475.

A species assigned tentatively to this genus was found growing on the bottom of one of the boats we used for survey work in the lagoon. The boat had been in the lagoon water continuously from June 30th to August 28th. Enteromorpha was also present.

Cladophoropsis sp.

Seaward reef 8136, 8137.

A member of the green algal community on the seaward reef. It was the dominant species at 200 feet from shore, but codominant with Dictyosphaeria at 300 feet.

Dictyosphaeria sp.

Seaward reef 8164; lagoon 8026, 8263.

The specimens have not been determined to species at the time of this writing. The specimen from the seaward reef was growing at 450 feet from shore and was not abundant. The other specimens were found on a reef

flat, 100 feet from shore just at low tide level. Also growing with Valonia on coral rocks on the lagoon side of the western reef.

Dictyosphaeria cavernosa (Forssk.) Borg.

Seaward reef 8137, 8390, 8482B; lagoon 8278, 8309, 8456, 8479, 8421; Betio, Tarawa Atoll 8632.

The common species of Onotoa Atoll. An abundant plant on the seaward reef, codominant with Cladophoropsis at 300 feet from the shore. It was common in the lagoon on coral knolls and rocks to a depth of 10 feet. Many of the hollow globular plants had split open into irregular flat masses. Collected also on the seaward reef of Betio Island, Tarawa Atoll.

Dictyosphaeria intermedia Weber Van Bosse

Seaward reef 8163, 8390B; reef flat northwest corner of Atoll 8421.

This species grew on the seaward reef at 350 feet from shore. It occurred also on the vast flat at the northwest end of the atoll where it was exposed at low tide. There are many collections of this genus remaining to be determined so other examples of this species will no doubt be found.

Dictyosphaeria setchellii Borg.

Seaward reef 8045.

This species has been found only once in the collections examined to date. It was collected on the ridges between the surge channels on the seaward reef. Here the surf washes over it even at low tide and it is never completely dry. Trabeculae inside the cells were many and measured 100 to 118 microns in length. Some of them were forked.

Enteromorpha sp.

Lagoon 8475.

An undetermined species was collected on the bottom of one of the boats used in the lagoon. See under Chaetomorpha. This species of Enteromorpha is only slightly branched.

Enteromorpha compressa (L.) Grev.

Lagoon 8181.

This Enteromorpha was growing at the base of the beach rock at high tide level in the lagoon, at the village of Taneang. A detailed paper analyzing the Halimedas is in manuscript and will be published separately soon.

Halimeda opuntia (L.) Lam.

Western Reef 8115B, 8249, 8249B, 8256A, 8256B, 8257, 8258, 8272A; lagoon 8318, 8398A, 8441, 8471; seaward reef 8478.

The most common and widely distributed species on the atoll. Most of the collections were from the western reef or coral knolls along the western side of the lagoon. Only one specimen was collected on the windward or seaward reef and it had been washed into a tide pool. Never abundant but generally growing in small patches or in a circle, turf-like, around the bases of the coral knolls, from just below the surface to a depth of 6 meters.

Halimeda bikinensis W. R. Taylor

Lagoon 8467.

This species described by Taylor (Plants of Bikini, University of Michigan Press, 1950) from Bikini was collected at only one location, in the deepest part of the lagoon, opposite the village of Aiaki, South Island. The bottom here was lime mud and sand. The depth of water was 48 feet.

Halimeda fragilis W. R. Taylor

Lagoon 8246, 8265, 8438; western reef 8272B.

This species was also first described by Taylor from Bikini. Specimens were collected from the western reef on both the lagoon and seaward side, and on coral knolls. It was found growing in water 3 to 12 feet deep, on lime sand and coral rock bottom.

Halimeda orientalis Gilbert

Lagoon 8409.

Apparently rare since only one collection was made. This was found in the western side of the lagoon between the reef Rakai Taka and Rakai Ati in 3 feet of water.

Halimeda stuposa W. R. Taylor

Western reef 8115; sand flats of Aonteuma 8113, 8481; lagoon 8221, 8277, 8359A, 8426.

This species was very abundant in the shallow sandy north portion of the lagoon and on the shallow sandy windward reef flats extending north east from Aonteuma. Fairly common in the shallow area covered with Thalassia. In many of these habitats the plants were partly or entirely exposed at low tide. One collection was made on the leeward reef west of Aonteuma Island, in a surge channel.

Halimeda taenicola W. R. Taylor

Western reef 8116, 8270; reef flat northeast of Aonteuma 8434.

This large and heavily calcified species was found growing on the leeward reef in surge channels and holes in the reef. Most of the specimens collected were in 6 to 11 feet of water. Found growing with H. *opuntia*.

Halimeda tridens (Ellis & Solander) Lamouroux f. *tripartita* (Barton) Collins.

Western reef 8271; lagoon 8468.

Not a common species. Found in the deepest part of the lagoon at 48 feet with *H. bikinensis*, and on the seaward edge of the leeward reef in 6 to 11 feet of water.

Microdictyon sp.

Lagoon 8263; tide pool, seaward reef 8478.

Much of the *Microdictyon* collected remain to be determined. These algae were very common along the shore of the lagoon and in the *Thalassia* beds. Specimen 8263 was growing on coral rocks with *Valonia* in the western area of the lagoon. Number 8478 was collected from a tide pool on the seaward reef with blue green algae.

Microdictyon umbilicatum Velley.

Lagoon 8409.

Growing with *Halimeda* in the western area of the lagoon.

Rhipilia orientalis A. and E. S. Gepp

Seaward reef 8370, 8380.

Fairly common as a fungus-like growth on the smooth walls of the surge channels on the seaward reef in shaded situations. Exposed at low tide only between waves. *Polysiphonia* was epiphytic on these plants.

Rhizoclonium hieroglyphicum (Ag.) Kütz.

North Island 8046, 8135, 8166, 8325.

A common member of the freshwater algal community in the babai pits, sometimes forming huge mats covering the entire surface. At other times mixed with the blue greens present. Also found growing in one of the fresh-water wells where the water level was 15 feet below the soil surface.

Valonia aegagrophila C. Ag.

Lagoon 8263; seaward reef 8287.

One collection was on coral rocks on the lagoon side of the western reef. The other was growing nearly 300 feet from shore on the seaward reef, mixed with other algae in the turf covering the reef.

Pyrrophyta

Exuviella sp.

Present in masses of Cladophoropsis and blue greens examined under the microscope at the time of collection.

Chrysophyta

(Diatoms)

Cocconeis sp. Present as an epiphyte on other algae growing at 600 feet from beach on seaward Transect A.

Licmophora sp.

A very common epiphyte, especially on material collected in August. Found growing on Laurencia, Ceramium and other algae on the seaward reef and in the back-ridge trough of this reef. Also common on algae collected from the lagoon.

Podocystis sp.

An occasional epiphyte on other algae.

Striatella unipunctata (Lyngbye) Agardh

Noticed as an occasional epiphyte on Jania and other red algae.

Unidentified diatom

An unidentified epiphyte covered plants of Dasya (8264) and Polysiphonia collected on the lagoon side of the western reef.

Euglenophyta

Euglena spp.

North Island 8138, 8166.

An uncommon member of the algal community in the bottom of the babai pits. With Anacystis and Phacus.

Phacus pleuronectes (O.F.Mull.) Duj.

North Island 8138.

The dominant organism present in water collected from the bottom of one of the babai pits. Euglena and a few ciliates the only other organisms present.

Phaeophyta

Turbinaria ornata J. Ag.

Seaward reef 8017, 8032, 8122, 8482A; lagoon 8075, 8221, 8276; reef flat northwest corner of atoll 8421; Rogeron Island, Majuro Atoll, Marshall Islands 8004.

The specimens from the seaward reef were picked up in the wash on the beach and probably came from beyond the coralline ridge, since this species did not occur on the reef flat itself. The only fertile specimen came from the seaward reef. The lagoon specimens were growing in irregular patches on coral fragments in 4½ feet of water, 200 feet from shore. The specimens from the reef flat at the northwest end of the atoll were growing exposed at low tide.

Padina sp.

Collected from the seaward reef (western reef) of the Island of Betio, Tarawa Atoll in September on the return trip. This alga was noticed as very common at the landing on Majuro, Marshall Islands, but not collected. Missing from the flora of Onotoa.

Rhodophyta

Ceramium sp.

Noticed as one of the fine epiphytic algae growing on many of the larger algae on the seaward reef and in the lagoon.

Centrocerus clavatulum (C. Agardh) Montagne

Seaward reef 8289.

Growing epiphytically over Laurencia and Jania on the outer end of the seaward reef. This species, occurring very commonly as a fine fuzzy epiphytic growth tightly attached and intertwined, was found in examining many other algae.

Dasya sp.

Lagoon 8261, 8264.

The two specimens above after preliminary examination seem to belong to this genus. Both grew on coral rock in the western side of the lagoon and were associated with Caulerpa and Polysiphonia.

Dictyurus purpurascens Bory

Reef northeast of Aonteuma 8358; reef shoals outside coralline ridge 8458.

One specimen was growing in water 8 feet deep at low tide and was growing in a hole in a coral head. The other on coral rock outside the coralline ridge on the seaward side of North Island.

Jania sp.

Lagoon 8026; seaward reef 8164, 8289.

These specimens have not been satisfactorily determined at the present writing. The one from the lagoon grew on a reef flat at the south end of North Island and was exposed at low tide. The other two were collected with *Laurencia* and *Centrocerus* on the outer end of the seaward reef in the red algal zone.

Jania capillacea Harvey

Seaward reef 8136, 8163, 8164, 8287.

A very common member of the algal turf community on the seaward reef. It first appeared in collections at 200 feet from shore, attached to *Cladophoropsis*. It became dominant at 350 feet. It was less common at 450 feet where it was growing on *Laurencia*. The following species of *Jania* replaced it here in abundance.

Jania decussato-dichotoma (Yendo) Yendo

Seaward reef 8163, 8164.

This species first appeared on the seaward reef at 350 feet from shore and became the dominant form of *Jania* on the outer end of the reef from 450 feet to 600 feet. At 450 feet it shared dominance with *Laurencia*, while from 500 to 600 feet it grew on and over the crustose *Porolithon onkodes*.

Laurencia sp.

None of the members of this genus have been determined to species at this writing.

Lagoon reef flat 8026; seaward reef 8164, 8287, 8289, 8367.

In the lagoon this alga was growing on the reef flat at the south end of North Island in pools and in some cases partly exposed at low tide. It grew on the seaward reef from 450 feet to 600 feet from shore associated with *Jania*, *Valonia*, *Centrocerus*. In August it was covered with epiphytic diatoms of the genus *Licmophora*. It was a dominant member of the reef flora at 450 feet. Several species are represented by the collections.

Polysiphonia sp.

Lagoon 8026.

The species of *Polysiphonia* examined to date are sterile and have not been determined to species. The genus grows as part of the filamentous fuzz on larger algae such as *Laurencia*, *Caulerpa*, *Jania*, and *Dasya*.

Porolithon gardineri (Foslie) Foslie

Seaward reef 8164.

The determination of the coralline red algae remains to be done. The two specimens identified tentatively as this species were collected in the one square foot transect on the seaward reef at 450 feet.

Porolithon onkodes (Heydrich) Foslie

Seaward reef 8136, 8137, 8163.

Only a tentative identification of this crustose alga. Found growing on pebbles in the tide pools of the seaward reef at 200, 300, and 350 feet from shore. Presumed to be the pavement crust at 550 feet and out over the coralline ridge.

Porolithon craspedium (Foslie) Foslie

Coralline ridge 8371, 8372.

The dominant coralline on top of the ridges separating the surge channels. Blue green algae, possibly an *Oscillatoria*, and *Jania* growing down in the creases between the blade-like structures.

Pterocladia sp.

The shoreward edge of the seaward reef is covered by a short red alga with only the bleached tips showing above the silt. After preliminary examination of this plant I have tentatively placed it in this genus. It is the dominant member of the algal community on the reef from 50 feet to 100 feet and is associated here with a few plants of *Cladophoropsis*.

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The Maldive Islands, Indian Ocean

by

F. R. Fosberg

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THE MALDIVE ISLANDS, INDIAN OCEAN

by
F. R. Fosberg 1/

Along the west coast of India and extending far south beyond the tip of peninsular India and across the equator stretch two long chains of atolls, the Laccadive group to the north and the Maldives to the South, with the isolated Minicoi Island between the two. These islands have been surveyed and described in the literature perhaps more thoroughly than most Pacific groups, as will be seen in examining the index to the Atoll bibliography in Island Bibliographies (Sachet and Fosberg 1955). Some historical and scientific highlights among the published works on the Maldives may be briefly recalled here.

In 1854-58, C. Defrémery and B. R. Sanguinetti published a French translation and edition of the voyages of Ibn Baṭūtah, an Arab voyager who visited the Maldives around 1343, lived there for a while, and gave an extremely vivid account of the islands and of life on them. This work has been considered the earliest descriptive account of the Maldives, and the manuscript may also be the earliest description of an atoll group. There are earlier references to these islands in ancient literature, but probably no detailed account.

A Frenchman, Pyrard de Laval, lived in the Maldives in the first years of the 17th century, after the ship Corbin, on which he travelled, was wrecked in 1602. His narration of his adventures is one of the most delightful travel accounts ever written, and includes much valuable information on the Maldives and their inhabitants.

Another "first", of course, for the Maldive group is the fact that the word atoll, or atollon, originated there. In this connection, a little-known paper by a French Navy officer may be of interest. In a letter to his former superior on the Corvette la Coquille, Commander L. I. Duperrey, with whom he had visited many Pacific Island groups, J. de Blosseville mentioned his visit to the Maldives in 1827 while serving on the Corvette la Chevrette. He wrote (1828, p. 700) "Vous vous rappelez sans doute que nous avons souvent parlé des rapports qui devaient exister entre les Atollons des Maldives et les groupes d'îles basses de la Polynésie; les traits de ressemblance sont parfaits, et je persiste à croire que la désignation de ce genre d'îles sous le nom d'Atollons, jetterait une grand clarté dans la nomenclature en devenant générale." Whether or not this young man was the first person to make this suggestion is not so important as the fact that our commonly used term for ringed-shaped low coral islands came from the Maldivian language and was generalized by observant voyagers more than a hundred years ago.

Some historical and other information on the Maldives is summarized in a work compiled by Bell (1883). From the point of view of natural

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history, besides the observations by Agassiz, Sewell, and others, the largest single contribution is J. Stanley Gardiner's monumental monograph: The fauna and geography of the Maldive and Laccadive Archipelagoes, 1901-1906, and other papers resulting from his work there. An account of the flora was published by J. C. Willis and J. Stanley Gardiner in 1901, extracts from which are given below in the list of plants.

Brief Report on a Trip to Malé Atoll, Maldives

There has been little of a scientific nature published on the Maldives since the results of the investigations of Prof. J. Stanley Gardiner mentioned above. Therefore, it seems worth while to place on record an account of a brief visit to Malé in April 1956, made possible through the courtesy of the government of His Highness Ali Amir Mohammed Farid Didi, Sultan of the Maldives and by financial aid from the Pacific Science Board. My sincere gratitude is expressed to the Hon. Philip K. Crowe, then U. S. Ambassador to Ceylon, for placing me in contact with the Maldivian authorities; to His Excellency, Ibrahim Ali Didi, Prime Minister of the Maldives, for an invitation to visit Male as a guest of the Maldivian Government, for courtesies and comforts extended to me while there, and for much information on the Maldives; to Messrs. Lajeki Ebrahim Didi, U. Abdullah, Adnan Husain, and Farouk Ismail, all of Malé, for many kind attentions and much information on the Maldives; and to Capt. H. Bloch, of M. S. Hugo Arlt, for many courtesies and pleasant company during the voyage from Colombo to Malé and return.

Malé is a large atoll lying north of the center of the Maldive Archipelago, about 470 miles WSW of Colombo, Ceylon. Malé Islet, the principal islet and capital of the group, lies on the southeast corner of the atoll, at Lat. 4° 10' N, Long. 73° 30' E. It has an area of about one-half square mile and a population of approximately 8,000; the total population of the archipelago is about 87,000.

Departure from Colombo aboard M. S. Hugo Arlt was early on the morning of April 8, 1956. During the voyage the sea was calm and the sun hot, but there was little breeze; the temperature dropped somewhat at night. We sighted Malé Atoll on the morning of April 10 and anchored in the lagoon about the middle of the forenoon. The Hugo Arlt carried a cargo of rice, flour, and other supplies for Malé, and was to pick up "Maldive fish", a special sort of dried bonito, to take to Ceylon.

The islets of Malé Atoll, seen on approaching and entering the lagoon, are mostly, with the exception of Malé itself, well covered by coconut trees, with some lower marginal forest at the tops of the beaches. Hululé Islet, immediately north of Malé, has a conspicuous road cut through the coconuts for its full length. A feature different from most Pacific atolls is the number of islets scattered within the lagoon, in addition to those along the peripheral reef. All except some very small ones are covered by coconut groves, surrounded, or partially so, by trees of several kinds. The outer reef on both sides of the channel is broad

and its outer edge is exposed at mid-tide. This outer margin, however, is of brownish rocks, not the pink algal ridge common on Pacific reefs. Except for this margin a few yards wide, the reef is covered with water up to the beach. A pale greenish color suggests that the reef flat is generally sandy.

The first close-up view of Malé Islet is a distinct surprise to one familiar only with Pacific atolls. Almost the entire islet is surrounded by a low stone wall. White stone buildings of two and even more stories dominate the lagoon shore. Centrally located is an ancient stone fort, said to be of Portuguese construction. Along the entire lagoon shore, enclosing a busy inner boat harbor, is a sea-wall of stone carefully laid but without mortar. This wall is necessary to protect the boats against the rough water of the lagoon during the monsoon season. During my visit, however, the lagoon surface remained like a sheet of glass. The wall is said to be 300 years old, and is in excellent shape though it requires annual repairs after battering by lagoon waves during the monsoon. Just outside the sea-wall the bottom drops off abruptly to 30 fathoms. This depth extends for some distance, to near the first lagoon islets, and provides an excellent anchorage for the Maldivian schooners and "bugaloes" as well as for visiting steamers such as the Hugo Arlt. Loading and unloading of steamers is by lighter.

Visitors are taken ashore in smartly rowed boats, conducted to the customs house, and treated with a quiet unfailing courtesy and hospitality that could serve as an example for officials of any country. One of the conspicuous features of the entire visit was the general kindness and friendliness of everyone, from the Prime Minister to the child on the street or the boatman in the harbor. Another was the complete lack of women in the crowds on the streets. In striking contrast to Ceylon, the only glimpses of Maldivian women were caught when an occasional attractive brown face peeped over the walls that line all the streets. Still another feature, notable in an Asiatic city, was the spotless cleanliness to be observed everywhere. Even Holland could do little more than match it. This cleanliness applied, so far as could be seen, to the streets, the shops, the houses, the courtyards and to the white blouses and sarongs with which most of the people were clothed.

The entire islet of Malé, except the green, or playing field on the east end and several parks or squares, is laid out in geometrically straight streets lined with stone or masonry walls about head high. Inside the walls and extending above them is a profusion of trees and ornamental shrubs of many kinds. The parks show a neatness and order that is comparable with that of a European formal garden. The green smooth lawns are not of grass but of the creeping hardy *Lippia nodiflora*, with bright green leaves and heads of tiny white flowers. Shrubs with bright flowers or colored foliage are planted as though laid out with the aid of surveying instruments. The court-yards of the houses are covered by a smooth layer of coarse white sand, largely made up of joints of the articulated calcareous green alga, *Halimeda*. This special sand is said to be collected on the beaches of some of the other islets at particular seasons when the waves wash it up.

An unusual feature of Malé is the large variety of cultivated plants, some of them scarcely expected on a coral atoll. It seems probable that one factor favoring some of them is the prevalence of walls that provide shelter from salt spray driven by the monsoon and storm winds. Coconut trees are relatively few on Malé Islet, itself. Breadfruit, mango, Thespesia, and Hibiscus tiliaceus are the most common trees. Inside the walls weeds seem to be nonexistent. Anything that grows is there because it is planted and permitted to grow. Botanizing for spontaneous plants is a fruitless pursuit except on the narrow flat strip outside the wall and on an unexpected tiny meadow-like area within the ramparts of the ancient fort. On these bits of relatively unused land small areas of well-trampled sod, scattered strand plants, weeds, clumps of bushes, and even a small thicket of an unpleasantly spiny Pandanus manage to maintain themselves. On the south side is a flat of broken coral pebbles and cobbles with very little vegetation. Familiar plants, to one used to Pacific atolls, found in these places include Scaevola sericea, Premna obtusifolia, Terminalia catappa, Morinda citrifolia, Eleusine indica, Fimbristylis cymosa, Tridax procumbens, Paspalum vaginatum, Eragrostis amabilis, Euphorbia hirta, Vernonia cinerea, Ochrosia oppositifolia, Guettarda speciosa, Clerodendrum inerme, Thuarea involuta, Wedelia biflora, Portulaca oleracea and many others. Other species are either quite unfamiliar or found chiefly on high islands in the Pacific. In the latter category are Turnera ulmifolia, Alysicarpus vaginalis, Indigofera tinctoria, Calotropis gigantea, Thespesia populnea, Lippia nodiflora, and Acalypha lanceolata. A full list of plants collected or seen, both wild and planted, is appended.

The only wild birds seen on Malé Islet were occasional crows, similar to those seen in Ceylon, and two individuals of a kind of large heron. Chickens, rats, cats, and three or more species of lizard were seen. Curiously, the Maldivian language is said to have no word for lizard, though they are common and conspicuous. Mosquitoes of at least two, and probably more, species are abundant. Both day- and night-biting kinds were found. A few flies were noticed.

During the three days on the atoll scarcely a breath of breeze stirred, and the heat was terrific, moderating only a little at night. This weather was said to be unusual and the monsoon was expected shortly.

A visit was made to two islets of Malé Atoll other than Malé itself. These were both uninhabited except for custodians who look after the coconut plantations and harvest nuts. One of these was Kuda Bados Islet, in the lagoon, the other was Furannafuri Islet, on the east reef, the third fairly large reef-islet north of Malé. These islets were fairly different in their physical aspect, but whether typical, respectively, of lagoon and reef islets it is not possible to say.

Kuda Bados, as other lagoon islets passed in reaching it, was made up of sand surrounded by narrow sandy beaches. The beach sand was white and fine. Small pieces of pumice were not uncommon. On the south side of this islet the beach was apparently being eroded, as the mat of coconut roots

was exposed for some distance and the small lagoon wavelets caused a swash to go up under the mat for an appreciable distance, though the surface layer of sand on top of the mat was disturbed for only the outer few decimeters. Shallow water with a sand bottom extended out 25 m or so, suggesting possibly this much erosion. The coconut trees are apparently unaffected by this process until they fall over. Evidences of similar erosion were noticed on parts of the shores of various islets where the beach is unprotected by a fringe of bushes.

Around the north part of the islet the sand forms a very low beach ridge, only 3 - 4 dm above high tide level and cut into by waves at that level. This ridge is covered by scrubby wood forming a narrow band. It is composed largely of Hibiscus tiliaceus, with some Hernandia, Guettarda, Pemphis, Calophyllum, Scaevola, and Messerschmidia, and with a little Pandanus, Suriana and Terminalia. This wood is dense but can be walked through at various places. This marginal band is scarcely developed on the south side of the islet.

The general level of the islet surface, except for the beach ridge, was very little above high tide level. The soil in a relatively open strip just inside the beach ridge was dark brown when moist, and almost black in the coconut grove. These soils did not change in the first 3-4 dm down. Earthworm casts were very abundant on the surface. Small fragments of brown consolidated material closely resembling the phosphate rock from Pacific Atolls were common in the soils, and larger fragments, up to cobble size, were scattered freely over the surface. Nothing like a continuous layer of this material was seen, nor were any Pisonia grandis trees found, such as would have been expected on a Pacific atoll with such phosphate rock. It is likely that a thousand years of close human occupation would have eliminated "useless" and easily destroyed trees like Pisonia, along with the birds that supplied the guano for the phosphate.

Under the coconut trees a few plants survived. Hibiscus, Calophyllum and a large Pandanus with edible fruit were scattered commonly in the groves, with some Morinda citrifolia and a few small Ochrosia saplings. Tacca and Crinum were common herbs, generally, with young plants of Flagellaria, tall spindly Abutilon, and occasional prostrate plants of Sida. In openings Dolichos formed mats. On open sand Nostoc colonies were locally abundant. Near the one house there was a patch of Turnera, a few small chlorotic breadfruit trees, a single tree each of Morinda and Tamarindus.

Chickens were common on this islet, scratching up the surface soil, possibly looking for earthworms. No other birds were seen except a small sandpiper.

The general aspect of this islet is fairly luxuriant, though the undergrowth is extremely sparse. Possibly the burning of piles of coconut trash, of which there is abundant evidence, may have something to do with this scarcity of undergrowth.

Furannafuri Islet on the east reef has an entirely different character than Kuda Bados. From a distance it appeared drier, the coconut trees were more sparse, and the brushy forest surrounding them more abundant. The islet was visited in the hope that it might show remnants of the original higher reef platform of the atoll, if there really had been such a platform. No such remnants, nor any consolidated rock, whatever, were found on the islet itself, though a few meters out from shore on the reef flat some extremely eroded snags of rock protrude above high-tide level. The nature of these was not investigated because of lack of time and because they could not be readily seen as the tide was high. The entire reef in this area was well covered by water.

The islet, elongated transversally to the reef, is a few hundred meters long and a hundred to two hundred meters wide. The lagoonward end, both the soil and the beach, is sandy and seems nowhere to reach more than about one meter above high tide level. As the outer end is approached the soil and beaches become more and more pebbly, until the outer hundred meters or more of the islet are a loose pebble flat surrounded by a sharp beach ridge a meter or more high of loose coral fragments from pebble to cobble size, very sharp and unworn. The soil, generally, on this islet, is a gray-brown more poorly developed type than on Kuda Bados, and nowhere was any phosphatic cemented rock seen.

Near the center but toward the lagoonward end is a well lined with concrete. Here, at the time of examination, the water level was about one meter or less below the general ground surface. The water was perceptibly brackish but would have been drinkable. This was near the end of the dry season of the year.

The general aspect of the vegetation is more luxuriant toward the inner end of the islet, possibly because of the sandy rather than pebbly nature of the soil. Here, besides a sparse stand of coconuts, the trees are mainly *Hibiscus tiliaceus*, *Calophyllum inophyllum*, and *Terminalia catappa*, with some *Ficus*, *Hernandia* and small *Messerschmidia*. A shrub layer, rather scattered but denser at the top of the beach, is mainly *Scaevola sericea* with some *Guettarda speciosa* and *Pemphis acidula*. This shrub layer is especially developed on the north side of the islet, and is very sparse at the south. In open and sparse places, especially near the center and to seaward, *Wedelia biflora* is common. The herbaceous layer is very sparse to almost absent, with locally some *Fimbristylis cymosa* and very locally, very stunted and dwarfed plants of *Boerhavia*.

Around the single house on the islet were a tree or two of *Moringa oleifera*, a scrubby lime, and a single small tree of the long-leafed edible species of *Pandanus*. All other *Pandanus* seen, the few trees around the beach on the inner end of the islet and thickets on the outer, were of the small-fruited very spiny inedible species.

Coconuts become more sparse on the outer part of the islet and are absent from the pebble flats on the extreme end. The outer end is largely occupied by an uneven thicket of Pemphis acidula, Cordia subcordata, and Pandanus, interspersed with pebble-lined pools containing a species of mangrove, Bruguiera. In one place, just back of the beach ridge, such a mangrove depression has been filled with pebble gravel, probably by storm waves, covering the bases of the mangrove trunks. The larger trees here are dead, the medium ones very sick-looking, and the small ones apparently quite healthy.

In the thickets there is no shrub or herb layer, no true undergrowth of any kind. However, its place is filled by stiff dead branches of Pemphis, low tangled limbs of Cordia and stilt roots of Pandanus, that make walking next to impossible except in openings between patches and clumps of thicket. The thicket changes from the north side to the south, and becomes locally dominated by Cordia, then by a mixture of Cordia and Pemphis, then by pure Pemphis, which extends well along the south shore toward the lagoon. Near the south shore are giant old "pollarded" Pemphis stumps, bushy with sprouts and up to almost a meter in diameter, that have obviously been cut back many times. Locally are Cordia of exactly the same habit, with even larger trunks.

Two crows were seen on this islet, and on the inner beach a flock of what seemed to be white terns, but these were not seen closely enough for identification.

Farucolofuri Islet was only examined from a distance from the lagoon side. Its central half is occupied by a dense coconut grove, thinning and becoming lower toward the ends, so that the fourth of it on each end is noticeably sparse, and by a pronounced scrub or scrub forest lining the shore and covering the ends of the islet; this is probably mostly of Pemphis. It is especially dense on the southwest corner where it seems a bit "wind-sheared", possibly from spray driven by the southwest monsoon. There is a sandy beach the entire length of the islet on the lagoon side, but in the center the beach is apparently subject to erosion, and a mat of coconut roots is exposed.

General features of what was seen of the atoll were the presence of broad bands of reef in the lagoon, covered by sand and irregular small growth of coral; extremely low altitude and little relief of the islets; lack of emerged reef conglomerate or of any development of beach rock; prevalence of islets within the lagoon; common occurrence of active beach erosion by lagoon waves; scarcity of birds; and general intensive human influence on and control of all features of the land surface.

On the basis of this brief visit, it is not possible to make any generalization whatever as to the atolls of the Maldive group. It is worth noting, however, that in many respects the observer gains an impression of dissimilarity with the Pacific atolls, of perhaps greater

complexity in geologic structure, and of a strong difference in human ecology, economy, and culture. These impressions strongly suggest that a longer investigation of this group of atolls would be desirable before much in the way of generalization on atoll geology and atoll ecology is attempted. It is clear that such an investigation by qualified scientists would be of benefit to the people of the Maldives, would be welcomed by their government, and that excellent cooperation could be expected.

Systematic list of plants of the Maldive Islands

In 1901 Willis and Gardiner compiled a list of 284 species of plants known to occur in the Maldive Islands, including about a dozen very dubious reports of plants not determined to species. The list is largely based on plants collected by Mr. Gardiner during his zoological and oceanographic investigations but includes also all species previously reported in the literature or sent in by other collectors. In addition to the systematic list the authors include a detailed description of the vegetation, considerations of economic plants of various sorts, a list of vernacular names, and a discussion of the origin of the flora.

With only two days at my disposal and many other observations to make, my collecting was of necessity very hasty and superficial compared with the thorough work of Gardiner. Nevertheless, my collection includes 29 species not mentioned in the Willis and Gardiner list. They are mostly weeds and cultivated plants. In the course of working up the collection the nomenclature used by Willis and Gardiner was largely revised. Therefore , it seems desirable to present a complete enumeration of the plants known from the archipelago, giving references to Willis and Gardiner, the native names recorded by them and those given me by Mr. Lajeki Ebrahim Didi, of Malé, for the plants I collected. For plants not recorded by Willis and Gardiner notes on occurrence and use are included. In addition to plants actually collected, 15 species cultivated in gardens in Malé and unreported by Willis and Gardiner are listed as seen but not collected; these reports can, except where otherwise noted, be regarded as fairly reliable, as these species are familiar ones.

Gardiner's collections were not available for examination, and the identification of a few plants seems open to doubt; for those a note has been made of what is probably the modern name of the plant, if it is different from that used by Willis and Gardiner. The doubtful records,not determined to species by them, have been excluded from the present list.

The total vascular flora, thus recorded here, is 323 species, to which are added two mosses and one Nostoc. Mr. W. W. A. Phillips has recently made a collection which I have not seen. Other species may be added when his list becomes available. A full set of my specimens will be deposited in the U. S. National Herbarium. The abbreviation W & G refers to the record for a species in Willis and Gardiner's list. Only the atolls from which the plant is recorded and the native names have been extracted. For further information the original paper can be consulted.

Note:

After this paper had been prepared, a letter was received from Mr. A. S. A. Packeer, Assistant Warden, Department of Wild Life in Colombo, reporting on the plants collected by Mr. Phillips. They are:

1. Lumnitzera coccinea (see L. littorea in systematic list)
2. Tournefortia argentea (see Messerschmidia argentea)
3. Scaevola frutescens (see S. sericea)
4. Calotropis gigantea
5. Pemphis acidula
6. Averrhoa bilimbi
7. Indigofera tinctoria
8. Rhoeo discolor
9. Wedelia biflora
10. Nephrolepis exaltata
11. Premna serratifolia (see P. obtusifolia)
12. Cyperus conglomeratus

We acknowledge with thanks the opportunity to add these records to this report.

ALGAE

Nostocaceae

Nostoc sp.
Malé Atoll, Malé Islet, common locally on bare sand, Fosberg 36829.

BRYOPHYTA

Calymperaceae

Calymperes hyophilaceum C. Müller
Malé, Kuda Bados I., on base of coconut tree, Fosberg 36899b, det. H. A. Miller.

PTERIDOPHYTA

Psilotaceae

Psilotum nudum (L.) Griseb.
Goifurfehendu; Haddumati; Suvadiva. W & G p. 112 as Psilotum triquetrum Sw. "Prumo."

Polypodiaceae

Asplenium nidus L.
Kolumadulu; Haddumati; Suvadiva. W & G p. 112 as Thamnopteris nidus L.

Nephrolepis exaltata (L.) Schott
Malé; S. Mahlos; Kolumadulu; Haddumati; Suvadiva. W.& G p. 112. "Kees fila", "Makunu hungal."
Probably not this species.

Thelypteris dentata (Forsk.) C. P. St John
Haddumati. W & G p. 112 as Nephrodium molle Desv.

GYMNOSPERMAE

Cycadaceae

Cycas circinalis L.
Malé, island near Malé I. W & G p. 111.

ANGIOSPERMAE

Pandanaceae

Pandanus hornei Balf. f. ?
Malé, Kuda Bados I., Fosberg 36899; Malé I.(in market), Fosberg 36899a, "karikio."
A large tree with spines close together and appressed, fruit heads large, fruit eaten.
Malé; S. Mahlos; Goifurfehendu; N. Mahlos; Addu, etc. W & G p. 104. "Karikeo", "Keeva" (in Addu Atoll).

Pandanus odoratissimus L.f.?
Malé, Malé I., forming thicket, Fosberg 36916."Bokio."
A rather small species with the leaves somewhat persistent, the spines fairly remote and diverging strongly, the heads small and the fruits inedible.
S. Mahlos; Addu, etc. W & G p. 104. "Bokeo", "Divihe keeva"(in Addu).

Gramineae

Apluda varia var. aristata L.
Goifurfehendu; Male; Kolumadulu; common in the whole group. W & G p. 109."Ona hui."

Bambusa arundinacea Willd.
Malé and other islands.W & G p. 111.

[Bambusa multiplex (Lour.) Rauschel?]
Maldives. W & G p. 111.

Bambusa vulgaris Schrad.
Miladumadulu. W & G p. 111.

Brachiaria subquadripara (Trin.) Hitchc.
Malé, Malé I., occasional in dense weedy sod, Fosberg 36864."Ono vina".

Cymbopogon nardus (L.) Rendle
Malé. W & G p. 110 as Andropogon nardus L. "Kasinji."

Digitaria sanguinalis (L.) Scop.
Goifurfehendu; Suvadiva. W & G p. 107 as Paspalum sanguinale (L.)Lam.
Tropical specimens referred to this species are more often actually D. ciliaris (Retz)Koel.

Eleusine aegyptiaca (L.) Desf.
Goifurfehendu; Miladumadulu. W & G p. 110.

Eleusine coracana (L.) Gaertn.
Grown here and there in the archipelago. W & G p. 110."Bimbi", "Beembi."

Eleusine indica (L.) Gaertn.
Malé, Malé I., common, Fosberg 36863. "Vina"= small grass.

<u>Eragrostis amabilis</u> (L.) W.& A.
Malé, Malé I., Fosberg 36860."Tumbuli vina."
Malé; Goifurfehendu. W & G p. 111 as <u>Eragrostis tenella</u> var. <u>plumosa</u> Stapf. "Tubuli hui", "Sannipoo."

<u>Ischaemum ciliare</u> Retz.
Malé. W & G p. 109. "Bileh-hui."

<u>Ischaemum muticum</u> L.
S. Mahlos; Goifurfehendu. W & G p. 109.

<u>Oplismenus compositus</u> (L.) Beauv.
S. Mahlos; Malé; Kolumadulu; Suvadiva; Addu. W & G p. 107."Ona hui."

<u>Oryza sativa</u> L.
Occasionally cultivated in some islands, but will not grow and set seed. W & G p. 108. "Handu."

<u>Panicum miliaceum</u> L.
N. Mahlos; Miladumadulu. W & G p. 107. "Bai."

<u>Paspalum vaginatum</u> Sw.
Malé, Malé I., local back of lagoon shore, Fosberg 36853.

<u>Pseudoraphis squarrosa</u> (L.f.) Chase
Malé; N. Mahlos; Suvadiva. W & G p. 110 as <u>Andropogon squarrosus</u> L.f. "Lancimo", "Lunsimoo."

<u>Saccharum officinarum</u> L.
Malé, Malé I., seen but not collected, Fosberg in 1956.
"Nearly all the larger islands of the group..." W & G p. 109."Udandi."

<u>Setaria italica</u> (L.) Beauv.
N. Mahlos. W & G p. 108. "Ura."

<u>Sorghum bicolor</u> (L.) Moench
"Formerly cultivated in the Maldives." W & G p. 110 as <u>Andropogon sorghum</u> Brot. "Zoowari."

<u>Spinifex squarrosus</u> L.
N. Mahlos; Goifurfehendu, etc. W & G p. 107.

<u>Stenotaphrum complanatum</u> Schrank
Kolumadulu. W & G p. 108.

<u>Thuarea involuta</u> (Forst.f.) R. & S.
Malé, Malé I., Fosberg 36822.
S. Mahlos; Goifurfehendu; common throughout archipelago. W & G p. 108. as <u>Thuarea sarmentosa</u> Pers.

<u>Zea mays</u> L.
Malé; Miladumadulu. W & G p. 109. "Donera", "Donala."

<u>Zoysia pungens</u> Willd.
Malé. W & G p. 108.

Cyperaceae

Cladium jamaicense Crantz
Addu. W & G p. 107.

Cyperus bulbosus Vahl
Malé, Malé I., common in grassy area on top of old fort, Fosberg 36912, "gok kulanduru."
Roots and tubers fragrant, sometimes used as incense.

Cyperus conglomeratus Rottb.
Malé, Kuda Bados I., on beach, Fosberg 36886.
Nut broadly elliptical, light chestnut brown.

Cyperus dubius Rottb.
Malé. W & G p. 106 as Mariscus dregeanus Kunth. "Hui ru", "Kalandura gundi."

Cyperus hyalinus Vahl
Goifurfehendu. W & G p. 105, as Pycreus pumilus Nees.

Cyperus javanicus Houtt.
Goifurfehendu. W & G p. 106 as Mariscus albescens Gaud. ?

Cyperus polystachyos Rottb.
Suvadiva; Addu. W & G p. 105 as Pycreus polystachyus Beauv. "Kuna."

Cyperus rotundus L.
Malé Malé I., on low waste ground near lagoon, Fosberg 36840. "dandukari."

Fimbristylis cymosa R. Br. var.
Malé, Malé I., common in open bare places, Fosberg 36848.
Malé; Goifurfehendu; Kolumadulu. W & G p. 106 as Fimbristylis spathacea Roth.

Araceae

Acorus calamus L.
Malé. W & G p. 105 "Huvago."

Alocasia indica (Roxb.) Schott
Malé. W & G p. 105. "Ma ala."

Colocasia esculenta (L.) Schott
Tiladumati; Addu; sparsely throughout archipelago. W & G p. 104 as Colocasia antiquorum Schott. "Ala."

[Cyrtosperma sp.?]
In some islands. W & G p. 104 as "identical with...Cyrtosperma edule Schott."

Raphidophora pertusa Schott
Haddumati. W & G p. 105.

Lemnaceae

<u>Lemna</u> <u>oligorrhiza</u> Kurz ?
Malé, Malé I., covering surface of water in well, Fosberg 36906.

Palmae

<u>Areca</u> <u>cathecu</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Miladumadulu; Malé; Suvadiva; Addu. W & G p. 102. "Femfora"; "Fo" or "Fakou" (nut).

<u>Cocos</u> <u>nucifera</u> L.
Malé, Malé I., Kuda Bados I., Furannafuri I., seen but not collected, Fosberg in 1956.
"Practically all the islands other than mere sandbanks." W & G p. 103. "Khari", "Kairi" (Addu), "Bo."

<u>Phoenix</u> <u>dactylifera</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Flagellariaceae

<u>Flagellaria</u> <u>indica</u> L.
Malé, Kuda Bados I., common in coconut plantation, only sterile plants seen, Fosberg 36896. "Vihalla gondi."

Bromeliaceae

<u>Ananas</u> <u>comosus</u> (L.) Merr.
Ari. W & G p. 99 as <u>Ananas</u> <u>sativus</u> L. "Anana."

Commelinaceae

<u>Commelina</u> <u>benghalensis</u> L.
Malé. W & G p. 102. "Diyamudoli."

<u>Commelina</u> <u>kurzii</u> Clarke
S. Mahlos; Malé; Haddumati; Suvadiva; Addu. W & G p. 102. "Tilo lagundi."

<u>Cyanotis</u> <u>cristata</u> Schultes f.
Haddumati. W & G p. 102.

<u>Rhoeo</u> <u>discolor</u> Hance
Malé; Addu. W & G p. 102 as <u>Rhaeo</u> <u>discolor</u>. "Re kandolu."

Liliaceae

<u>Asparagus</u> <u>racemosus</u> Willd.
Malé. W & G p. 101. "Satavaru."

<u>Cordyline</u> <u>terminalis</u> (L.) Kunth
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

<u>Gloriosa</u> <u>superba</u> L.
Malé; S. Mahlos; Goifurfehendu; northern half of Archipelago. W & G p. 101. "Wihelia-gundi."

Amaryllidaceae

<u>Crinum</u> <u>asiaticum</u> L.
Goifurfehendu; everywhere in archipelago. W & G p. 99.

<u>Hippeastrum</u> <u>puniceum</u> (Lam.) Urb. ?
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

<u>Hymenocallis</u> <u>littoralis</u> (Jacq.) Salisb.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956. This is possibly the plant reported by W & G as <u>Pancratium</u> sp.

<u>Pancratium</u> <u>zeylanicum</u> L.
Suvadiva. W & G p. 100.

Dioscoreaceae

<u>Dioscorea</u> <u>alata</u> L.
Malé; all over the group. W & G p. 101. "Billi-kattala."

<u>Dioscorea</u> <u>fasciculata</u> Roxb.
Malé. W & G p. 101. "Kurukuru."

<u>Dioscorea</u> <u>globosa</u> Roxb.?
Malé. W & G p. 101. "Mativa", Mathe-wa."

<u>Dioscorea</u> <u>pentaphylla</u> L.
Malé; Tiladumati; Addu. W & G p. 101. "Kattela."

<u>Dioscorea</u> <u>purpurea</u> Roxb.?
Malé. W & G p. 101. "Bilek-kattala."

<u>Dioscorea</u> <u>rubella</u> Roxb.?
Malé. W & G p. 101. "Kattala."

Taccaceae

<u>Tacca</u> <u>leontopetaloides</u> (L.) O. Kuntze
Malé, Kuda Bados I., Fosberg 36883. "hit tala."
Malé; Goifurfehendu; "common in the whole archipelago." W & G p. 100 as <u>Tacca</u> <u>pinnatifida</u> Forst. "Hitala", "Hittala", Heith-thala."

Musaceae

<u>Musa</u> <u>sapientum</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Tiladumati; N. Mahlos; Suvadiva; most islands. W & G p. 99. "keo", "dongkeo."

Casuarinaceae

Casuarina equisetifolia L.
Malé, Malé I., cultivated, trimmed into hedges, seen but not collected, Fosberg in 1956.

Piperaceae

Piper betle L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé; Miladumadulu; Addu; all atolls. W & G p. 93."Billi"; "Wang" and "Billaton" (Addu) are names for leaf.

Piper nigrum L.
Malé. W & G p. 93.

Moraceae

Artocarpus altilis (Park.) Fosb.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé; S. Mahlos; N. Mahlos; Goifurfehendu; "nearly every inhabited island of the group." W & G p. 98 as Artocarpus incisa L.f. "Bambukea", "Banke"(Addu).

Artocarpus heterophylla Lam.
Malé. W & G p. 98 as Artocarpus integrifolia L.f."Sakkeyo."

Ficus benghalensis L. ?
Malé; N. Mahlos. W & G p. 97. "Nika."

Ficus infectoria Roxb.
Malé, Malé I., occasional, banyan-like but multiple trunk and aerial roots not much developed, Fosberg 36845 ?"Dumbu."
Malé. W & G p. 98. "Dumbu."

Ficus mysorensis Heyne?
Malé, Malé I., one tree seen on playground near outer beach, Fosberg 36821. "Fili."
Possibly the same as the Ficus sp. with this vernacular name reported by W & G p. 97.

Ficus religiosa L.
Malé; Fua Mulaku; Suvadiva. W & G p. 98. "Boi."

Ficus retusa L. ?
Malé. W & G p. 98. "Kudehi."

Urticaceae

Fleurya interrupta Gaud.
Malé; Kolumadulu; W & G p. 98. "Gakehebuli."

Pilea microphylla L.
Malé, Malé I., in crevices in walls along streets, Fosberg 36914.

Pouzolzia indica Gaud.
Malé; Goifurfehendu; Kolumadulu. W & G p. 99. "Giteyokoli", "Gitakoli."

Polygonaceae

Antigonum leptopus H. & A.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 93.

Nyctaginaceae

Boerhavia diffusa L.
Male; Goifurfehendu; Kolumadulu; common throughout archipelago. W & G p. 90. "Burandagondi", "Nanubedi."

Boerhavia erecta L.
Malé, Malé I., weedy sod back of beach, Fosberg 36859.

Boerhavia repens L.?
Malé, Male I., rare in dense weedy sod back of beach, Fosberg 36869, 36870. "Burunda gondi."
No. 36869 abnormal, possibly infected by Albugo.
Malé, Furannafuri I., common along trails in sparse coconut plantation, Fosberg 36901. "Buranda gondi." Root eaten.

Bougainvillea spectabilis Willd.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 91.

Mirabilis jalapa L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 91. "Asuraffole re"(red), "Asuraffole hudu" (white), "Re asaruman", "Asarumu."

Pisonia aculeata L.?
Kolumadulu. W & G p. 91.

Pisonia grandis R. Br.
Malé, Malé I., doubtfully seen, cultivated, but not collected, Fosberg in 1956.
Malé; Kolumadulu. W & G p. 91 as Pisonia morindaefolia Br. "Los."

Amaranthaceae

Achyranthes aspera L.
Malé; S. Mahlos. W & G p. 92. "Karhi léibú."

Aerua lanata L.
Male; S. Mahlos; Goifurfehendu; Kolumadulu; everywhere except in Addu. W & G p. 92."Hudufupila."

Amaranthus caudatus L.
Malé. W & G p. 92."Raidadisagu."

Amaranthus _spinosus_ L.
Malé. W & G p. 92.

Amaranthus _tricolor_ L.
Malé. W & G p. 92 as _Amaranthus_ _gangeticus_ L.

Amaranthus _viridis_ L.
Malé, Malé I., Fosberg 36844."Masagu," eaten as potherb.
Malé. W & G p. 92. "Massagu."

Celosia _argentea_ L.
Haddumati. W & G p. 92.

Nothosaerua _brachiata_ Wight
Malé, Malé I., Fosberg 36868. "huduhup pila."
Malé. W & G p. 92.

Aizoaceae

Sesuvium _portulacastrum_ L.
Malé. W & G p. 74. "Mapijja."

Portulacaceae

Portulaca _oleracea_ L.
Malé, Malé I., common in open places, Fosberg 36847.
"Raid geda" eaten as potherb.
Malé. W & G p.53. "Rai-geda."

Portulaca _quadrifida_ L.
Malé, Malé I., local, Fosberg 36831.
Malé. W & G p. 54. "Makuna-fila"

Portulaca _tuberosa_ (Roxb.) Trim.
Malé; Goifurfehendu; Kolamadulu. W & G p. 54. "Riindu-filia."

Annonaceae

Annona _muricata_ L.
Malé; fairly common throughout northern atolls; Suvadiva; Addu. W & G p. 52. "Anona", "Ata."

Annona _squamosa_ L.
Malé; Addu. W & G p. 52. "Ata."

Artabotrys _odoratissimus_ R. Br.
Malé. W & G p. 51. "Chunpápool."

Menispermaceae

Tinospora _cordifolia_ Miers
Malé. W & G p. 52.

Lauraceae

<u>Cassytha</u> <u>filiformis</u> L.
Malé, Kuda Bados I., climbing over trees, not abundant, Fosberg 36893. "Vela buli."
Malé; Goifurfehendu; Kolumadulu. W & G p. 93. "Dom velam buli," "Vele buli."

Hernandiaceae

<u>Gyrocarpus</u> <u>jacquini</u> Roxb.
S. Mahlos; through the whole group. W & G p. 69.

<u>Hernandia</u> <u>sonora</u> L.
Malé, Kuda Bados I., common in scrub forest on beach ridge, Fosberg 36889. "Kandu."
Malé; Goifurfehendu; S. Mahlos; Kolumadulu; common in whole group. W & G p. 94 as <u>Hernandia</u> <u>peltata</u> Meissn. "Kando", "Maskando", "Kadu."

Papaveraceae

<u>Argemone</u> <u>mexicana</u> L.
Malé; Addu. W & G p. 52. "Zaggumu."

Capparidaceae

<u>Cleome</u> <u>viscosa</u> L.
Goifurfehendu; Miladumadulu; Malé. W & G p. 53. "Răbeburi."

<u>Gynandropsis</u> <u>gynandra</u> (L.) Briq.
Goifurfehendu; Kolumadulu. W & G p. 53 as <u>Gynandropsis</u> <u>pentaphylla</u> DC.

Cruciferae

<u>Brassica</u> <u>juncea</u> Hook.f. & Th.
Malé. W & G p. 52. "Revi."

Moringaceae

<u>Moringa</u> <u>oleifera</u> Lam.
Male, Kuda Bados I., one tree in coconut plantation, Fosberg 36885. "Morunga" leaves and fruit eaten as potherb.
Malé; Kolumadulu; common in all the group. W & G p. 62 as <u>Moringa</u> <u>pterygosperma</u> Gaertn. "Muranga."

Crassulaceae

<u>Kalanchoe</u> <u>pinnata</u> (Lam.) Pers.
Malé, Malé I., occasional, Fosberg 36823. "Fatungas fala."
Malé; very sparsely through the group. W & G p. 68 as <u>Bryophyllum</u> <u>calycinum</u> Salisb. "Bodu faru," "Fatunfaifila."

Rosaceae

Rosa sp.
Malé; Miladumadulu. W & G p. 68. "Fini-fenma."

Leguminosae

Acacia farnesiana (L.) Willd.
Malé; Goifurfehendu; Kolumadulu; common in south of group, rare in north. W & G p. 67. "Bés-góbili."

Adenanthera pavonina L.
Malé. W & G p. 67.

Albizzia lebbek L.
Malé, Malé I., one tree seen in open flat at end of island, Fosberg 36838. "Riitikas."

Alysicarpus vaginalis (L.) DC.
Malé, Malé I., common in dense weedy sod back of beach, Fosberg 36866.

Caesalpinia bonduc (L.) Roxb.
Goifurfehendu; Kolumadulu; Malé; common in whole archipelago. W & G p. 65 as Caesalpinia bonducella Fleming. "Karikuburu."

Caesalpinia major (Medic.) Dandy & Exell ?
Maldives. W & G p. 65 as Caesalpinia bonduc?

Caesalpinia pulcherrima (L.) Sw.
Malé. W & G p. 66. "Fatangu."

Canavalia ensiformis DC.
Kolumadulu. W & G p. 64. "Talafuri."

Canavalia lineata DC.
Malé; S. Mahlos. W & G p. 64. "Manifa."

Cassia auriculata L.
Malé. W & G p. 66. "Ranawia."

Cassia occidentalis L.
Malé; Miladumadulu. W & G p. 66. "Kuhada."

Cassia sophora L.
Goifurfehendu; Malé; Kolumadulu; Addu; Suvadiva. W & G p. 66. "Rana-rua."

Cassia surattensis Burm. f.
Malé, Kuda Bados I., rare in semi-open place, Fosberg 36895."Rana ura."
Malé. W & G p. 66 as Cassia glauca var. suffruticosa Koenig. "Rana-ura."

Cassia tora L.
Goifurfehendu. W & G p. 66.

Clitoria ternatea L.
Goifurfehendu. W & G p. 65.

Crotalaria retusa L.
Malé, Malé I., rare in coconut plantation, Fosberg 36898. "Viha giguna."
Malé; Haddumati. W & G p. 62. "Viha-giguni."

Delonix regia (Boj.) Raf.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 66 as Poinciana regia Boj. "Kandi-toli."

Desmodium gangeticum (L.) DC.
S. Mahlos. W & G p. 63.

Desmodium triflorum (L.) DC.
Kolumadulu. W & G p. 63. "Hekoopie."

Desmodium umbellatum (L.) DC.
Goifurfehendu; very common in archipelago. W & G p. 63.

Dolichos lablab L.
Malé, Kuda Bados I., climbing in bushes and trees and creeping on ground in open or partially open places, Fosberg 36894. "Du himeri", bean eaten by some people.
Malé; Haddumati. W & G p. 65. "Himerri."

Entada scandens Benth.
Malé. W & G p. 67.
Probably is E. pursaetha DC. (vide Brennan, Kew Bull. 1955: 161-170) but since only the seeds are known and these were found on the beach the species can scarcely be determined and the plant is probably not a member of the Maldive flora.

Erythrina indica L.
Malé. W & G p. 64. "Berebedi."

Indigofera enneaphylla L.?
Malé, Malé I., common in grassy area on top of old fort, Fosberg 36911.

Indigofera tinctoria L.
Malé, Malé I., occasional, Fosberg 36828, 36862. "Fang hiti."
Malé; S. Mahlos; Goifurfehendu; Kolumadulu. W & G p. 62. "Vihafilia."

Mimosa pudica L.
Malé. W & G p. 67. "Ladu."

Pachyrhizus erosus (L.) Urb.
Malé. W & G p. 65 as Pachyrhizus angulatus Rich. "Viha-toli."

Peltophorum pterocarpum (DC.) Backer ex K. Heyne
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Phaseolus lunatus L.
Malé. W & G p. 64. "Himeri."

Samanea saman (Jacq.) Merr.
Male, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Sophora tomentosa L.
Malé; Goifurfehendu. W & G p. 65.

Tamarindus indica L.
Malé; Goifurfehendu; Addu; "sparsely near villages everywhere." W & G p. 67. "Helebeli."

Tephrosia purpurea var. pumila Baker
S. Mahlos. W & G p. 63.

Tephrosia tenuis Wall
Malé. W & G p. 63."Fesko."

Vigna marina (Burm.) Merr.
Kolumadulu. W & G p. 64 as Vigna lutea A. Gray.

Oxalidaceae

Averrhoa bilimbi L.
Malé, Malé I., commonly planted around houses, Fosberg 36907.
Malé. W & G p. 58. "Bilimagu."

Averrhoa carambola L.
Malé. W & G p. 58. "Kamaraga."

Zygophyllaceae

Tribulus terrestris L.
Malé. W & G p. 58.

Rutaceae

Citrus aurantifolia (Christm.) Swingle
Malé, Furannafuri I., seen but not collected, Fosberg in 1956.
Maldives; "generally cultivated." W & G p. 59 as Citrus medica var. acida Brandis."Limbo."

Citrus aurantium L.
Fua Mulaku. W & G p. 59. "Moli."

Citrus decumana L.
Malé; Addu. W & G p. 59. "Niyaduru."

Citrus limon Burm.f.
Miladumadulu. W & G p. 59 as Citrus medica var. Limonum. "Bodu Limbo" (big lime).

Murraya koenigii Spreng.
Malé. W & G p. 58. "Hikundi."

<u>Triphasia</u> <u>trifoliata</u> DC.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé; "very scarce in the N., and not in the S., of Archipelago." W & G p. 58. "Kudalimbo" (small lime).

Simarubaceae

<u>Suriana</u> <u>maritima</u> L.
Malé, Malé I., occasional at top of beach, Fosberg 36890. "halaveli."
Malé; Goifurfehendu. W & G p. 59. "Hala veli", "Halia veli."

Meliaceae

<u>Azadirachta</u> <u>indica</u> Juss.
Malé, Mále I., planted, Fosberg 36908. "Hiti."
Malé. W & G p. 59. "Hiti."

Polygalaceae

<u>Polygala</u> <u>ericptera</u> DC.
Goifurfehendu; S. Mahlos; "fairly common everywhere in the north." W & G p. 53.

Euphorbiaceae

<u>Acalypha</u> <u>amentacea</u> vars.
Malé, Mále I., cultivated, Fosberg 36880.
This is the plant with red leaves commonly called <u>A</u>. <u>wilkesiana</u> M.-A. The form called <u>A</u>. <u>wilkesiana</u> var. <u>circinata</u> was seen also, but not collected.

<u>Acalypha</u> <u>indica</u> L.
Malé; Goifurfehendu; Addu. W & G p. 96. "Vaffufuli."

<u>Acalypha</u> <u>lanceolata</u> Willd.
Malé, Malé I., locally common in dense weedy sod back of beach, Fosberg 36871.
Malé; Goifurfehendu; Kolumadulu; Suvadiva; Addu. W & G p. 97 as <u>Acalypha</u> <u>fallax</u> M.-A. "Bissagu", "Cave."

<u>Acalypha</u> <u>paniculata</u> Miq.
Malé. W & G p. 96. "Dagundi kandi", "Meia-ságu."

<u>Agyneia</u> <u>bacciformis</u> A. Juss.
Addu. W & G p. 95.

<u>Aleurites</u> <u>moluccana</u> (L.) Willd.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

<u>Codiaeum</u> <u>variegatum</u> (L.) Bl.
Malé, Malé I., cultivated, Fosberg 36879. "Domphai baguitsa."

<u>Croton</u> <u>tiglium</u> L.
Kolumadulu. W & G p. 96.

Euphorbia atoto Forst.
Goifurfehendu; Male; frequent in group. W & G p. 94. "Kiru tina."
Very probably not this species, possibly E. chamissonis Boiss.

Euphorbia clarkeana Hook. f.
Male, Male I., occasional to common locally in waste places, Fosberg 36830.
This may be what W & G report as E. thymifolia L. from Kolumadulu Atoll.

Euphorbia heterophylla L.
Male, Male I., very common in waste places, Fosberg 36850.

Euphorbia hirta L.
Male, Male I., common, Fosberg 36867. "Kirutina."
Male; S. Mahlos. W & G p. 95 as Euphorbia pilulifera L."Kirutina."

Euphorbia hypericifolia var. parviflora L.
S. Mahlos; Kolumadulu; Addu. W & G p. 94. "Kerutina."

Euphorbia thymifolia L.
Kolumadulu. W & G p. 95.

Glochidion littorale Forst.?
Male. W & G p. 96. "Emboo."

Manihot esculenta Crantz
Male, Male I., cultivated, seen but not collected, Fosberg in 1956.
Male. W & G p. 96 as Manihot utilissima Pohl.

Micrococca mercurialis (L.) Benth.
Male, Male I., rare, Fosberg 36872.

Pedilanthus tithymaloides Poit.
Male; Addu. W & G p. 94. "Kala kiru."

Phyllanthus amarus Schum. & Thonn.
Male, Male I., occasional in weedy sod back of beach, Fosberg 36861.
Male; Goifurfehendu; Kolumadulu. W & G p. 96 as Phyllanthus niruri L.

Phyllanthus debilis Klein ex Willd.
Male, Male I., common in weedy places, Fosberg 36856.
"Kaalu lumbo."

Phyllanthus distichus M.-A.
Male. W & G p. 96. "Gobili."

Phyllanthus maderaspatensis L.
Male, Male I., common, Fosberg 36873. "Kudihiti."
Male; S. Mahlos; Goifurfehendu; Kolumadulu. W & G p. 95. "Meia limbo", "Kudingke."

Phyllanthus nivosus Bull
Malé, Malé I., cultivated, Fosberg 36877.
This should probably be placed in a separate genus, usually called Breynia Forst., but this generic name is a later homonym of Breynia L. and no name is available for the genus at present.

Phyllanthus urinaria L.
S. Mahlos; Goifurfehendu. W & G p. 95.

Ricinus communis L.
Malé, Malé I., common, Fosberg 36843. "Raing amanaka."
Malé; Goifurfehendu; Kolumadulu; "all over the islands." W & G p. 97. "Amanaka."

Trewia nudiflora L.?
Malé. W & G p. 97. "Varukundu."

Anacardiaceae

Mangifera indica L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 62.

Sapindaceae

Allophylus cobbe Bl.
Malé; S. Mahlos; Goifurfehendu; Kolumadulu. W & G p. 61. "Dom Moussa."

Cardiospermum helicacabum L.
Malé. W & G p. 61.

Dodonaea viscosa L.
Malé; Goifurfehendu; Kolumadulu. W & G p. 61. "Kudiruvali."

Rhamnaceae

Colubrina asiatica (L.) Brongn.
Malé; S. Mahlos; N. Mahlos. W & G p. 60. "Ra-rohi."

Zizyphus jujuba (L.) Lam.
Malé, Malé I., Fosberg 36875. "Kun'nar."
Malé; Goifurfehendu; Kolumadulu; common in whole group. W & G p. 60. "Kunnáru", "Konara."

Vitaceae

Vitis linnaei Wall?
Malé. W & G p. 60.

Tiliaceae

Corchorus aestuans L.
Malé; Goifurfehendu; Kolumadulu. W & G p. 57 as Corchorus acutangulus Lam. "Hambaddi", "Hiriddigga", "Kaduru", "Gethawooley."

<u>Corchorus</u> <u>capsularis</u> L.
Malé. W & G p. 57. "Bulúkiya."

<u>Muntingia</u> <u>calabura</u> L.
Male, Male I., spontaneous in crevice in old fort, Fosberg 36914.
"Jaam" fruit eaten.

Malvaceae

<u>Abutilon</u> <u>indicum</u> (L.) Sweet
Malé, Kuda Bados I., occasional in coconut plantation, Fosberg 36897.
"Ma bula" leaves eaten in curry.
Malé; Goifurfehendu; very common everywhere. W & G p. 55. "Má-Bulá."

<u>Gossypium</u> <u>barbadense</u> var. <u>acuminatus</u> Roxb.
Malé; Goifurfehendu; Kolumadulu; "sparingly cultivated in whole group."
W & G p. 56. "Bodu kafa."

<u>Gossypium</u> <u>herbaceum</u> L.
Malé, Malé I., occasional, Fosberg 36841. "Ok kafa."
A shrub 2 m tall growing spontaneously, with some doubt referred to this species.
Malé; N. Mahlos. W & G p. 56. "Kafa."

<u>Hibiscus</u> <u>abelmoschus</u> L.?
Suvadiva; Kolumadulu. W & G p. 56.

<u>Hibiscus</u> <u>rosa-sinensis</u> L.
S. Nilandu. W & G p. 56.

<u>Hibiscus</u> <u>solandra</u> L'Her.
Malé, Kuda Bados I., rare in plantation, Fosberg 36884.
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; "sparingly everywhere in group. W & G p. 55. "Nadu-kandi", "Kukulufaifila."

<u>Hibiscus</u> <u>tiliaceus</u> L.
Malé, Malé I., common on seaward flats, Fosberg 36832. "Dika."
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; common throughout group.
W & G p. 56. "Diga."

<u>Hibiscus</u> (ornamental hybrids)
Malé, Malé I., several cultivated ornamental hybrid Hibiscus seen, but not collected, Fosberg in 1956.

<u>Sida</u> <u>carpinifolia</u> L.
Malé; Haddumati. W & G p. 55. "Mirajjé sai."

<u>Sida</u> <u>humilis</u> Willd.
Malé, Malé I., Fosberg 36846, 36854. "Weodikka", "reodikka."
Malé; S. Mahlos; Addu. W & G p. 54. "Veyo-diggá."

<u>Thespesia</u> <u>populnea</u> (L.) Sol. ex Correa
Malé, Malé I., common generally, especially along lagoon shore, Fosberg 36852. "Hirundu." Wood used for freeboard of boats.
Malé; "all over-archipelago." W & G p. 56. "Hirundu."

Bombacaceae

Adansonia digitata L.
Male; W & G p. 57. "Foh."

Ceiba sp.
Male, Male I., a large buttressed tree probably belonging to this genus seen but not collected, Fosberg in 1956.

Sterculiaceae

Abroma augusta L.
Male. W & G p. 57. "Garada."

Guttiferae

Calophyllum inophyllum L.
Male, Kuda Bados I., common in and around coconut plantation, Fosberg 36887. "Funa."
Male; N. Mahlos; very common in S. of group. W & G p. 54. "Funa."

Turneraceae

Turnera ulmifolia var. elegans (Otto) Urb.
Male, Male I., common generally especially along lagoon shore, Fosberg 36849, also seen on other islets.
This is large-leafed, yellow-flowered form of this species.

Passifloraceae

Passiflora coerulea L.
Male. W & G p. 72.

Passiflora edulis Sims
Male, Male I., cultivated, seen but not collected, Fosberg in 1956.

Caricaceae

Carica papaya L.
Male, Male I., cultivated, seen but not collected, Fosberg in 1956.
Male; S. Mahlos; Goifurfehendu. W & G p. 72. "Falo."

Cucurbitaceae

Benincasa cerifera Savi.
Male. W & G p. 73. "Fufu."

Citrullus colocynthis Schrad.?
Male. W & G p. 73. "Kara."

Citrullus vulgaris Schrad.
"Commonly cultivated in the Archipelago." W & G p. 73.

Cucumis sativus L.
Malé; S. Mahlos; Kolumadulu; Miladumadulu. W & G p. 73. "Kekuri."

Cucurbita maxima Duch. ?
Malé; Addu. W & G p. 74.

Cucurbita moschata Duch.
Malé; Addu. W & G p. 74.

Cucurbita pepo L.
Malé. W & G p. 74. "Burubo."

Luffa aegyptiaca Mill.?
Malé. W & G p. 73. "Tora."

Momordica charantia L.
Malé. W & G p. 73. "Faga."

Trichosanthes cucumerina L.
N. Mahlos; Addu. W & G p. 73.

Lythraceae

Lagerstroemia indica L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Lawsonia inermis L.
Malé, Malé I., planted in park, Fosberg 36915.
Leaves said to be crushed in milk to impart red color to women's hands.
Malé; Goifurfehendu. W & G p. 71 as Lawsonia alba Lam. "Heena", "Innapa."

Pemphis acidula Forst.
Malé, Kuda Bados I., abundant at top of beach, on sand, Fosberg 36891. "Kuredi" wood used for keels of boats.
Malé; Goifurfehendu; Kolumadulu; S. Mahlos; "common in all the Maldives." W & G p. 71. "Dhadukuradi", "Kuredi", "Kuradu."

Sonneratiaceae

Sonneratia alba J. Sm.
Malé; Addu; Miladumadulu. W & G p. 71 as Sonneratia acida L. "Kulowa."

Punicaceae

Punica granatum L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé; N. Mahlos; S. Mahlos; Kolumadulu. W & G p. 72. "Annáru."

Rhizophoraceae

Bruguiera cylindrica (L.) Bl.
Malé, Furannafuri I., common around saline pools near outer end of islet, Fosberg 36903. "Kandu" embryo radicle boiled and eaten.
Goifurfehendu; Kolumadulu; Miladumadulu. W & G p. 68 as Bruguiera caryophylloides Bl. "Kandu."

<u>Rhizophora</u> <u>mucronata</u> Lam.
Addu; Suvadiva; "in damp jungle all over the group." W & G p. 68.

Combretaceae

<u>Lumnitzera</u> <u>littorea</u> (Jack) Voigt
Malé. W & G p. 69 as <u>Lumnitzera</u> <u>coccinea</u> W. & A. "Kandu."

<u>Lumnitzera</u> <u>racemosa</u> Willd.
Suvadiva. W & G p. 69.

<u>Terminalia</u> <u>catappa</u> L.
Malé, Malé I., occasional in scrub at top of seaward beach, Fosberg 36833. "Mididi."
Malé; Kolumadulu; Goifurfehendu; Suvadiva; Addu; abundant all over the group. W & G p. 69. "Midili", "Medili", "Dommadu", "Gobu."

Lecythidaceae

<u>Barringtonia</u> <u>asiatica</u> (L.) Kurz
Malé, Furannafuri I., thicket in from beach, Fosberg 36900. "Kimbi."
Malé; S. Mahlos; Suvadiva; Addu. W & G p. 70 as <u>Barringtonia</u> <u>speciosa</u> Forst. "Kimbi."

Myrtaceae

<u>Eugenia</u> <u>jambolana</u> Lam.
Malé. W & G p. 70. "Lami."

<u>Eugenia</u> <u>jambos</u> L.
Malé; Addu. W & G p. 70. "Jumbu?"

<u>Eugenia</u> <u>javanica</u> Lam.
Malé; Malé I., cultivated, Fosberg 36876. "Jamburo." Fruit eaten.
Malé? W & G p. 70. "Jamburool."

<u>Eugenia</u> <u>malaccensis</u> L.
Malé; Addu. W & G p. 70. "Jumbu?"

<u>Psidium</u> <u>guajava</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 70. "Féru."

Araliaceae

<u>Polyscias</u> <u>guilfoylei</u> (Bull) Bailey
Haddumati. W & G p. 74 as <u>Aralia</u> <u>guilfoylei</u> F. von M.

Myrsinaceae

<u>Ardisia</u> <u>humilis</u> Vahl
Suvadiva; Addu. W & G p. 79.

Sapotaceae

Mimusops elengi L.
Malé. W & G p. 80. "Munima."

Oleaceae

Jasminum auriculatum Vahl
Malé. W & G p. 80. "Kudima."

Jasminum azoricum L.
Malé, Male I., cultivated, Fosberg 36881. "Glenura ma."

Jasminum officinale f. grandiflorum (L.) Kobuski
Malé, Malé I., cultivated, Fosberg 36882. "Wandu ma."
Malé; S. Mahlos; Goifurfehendu; Kolumadulu. W & G p. 80 as Jasminum grandiflorum L. "Huwanduma."

Jasminum sambac (L.) Ait.
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; Haddumati; Addu. W & G p. 80. "Irudema", "Re Irudema."

Apocynaceae

Catharanthus roseus (L.) G. Don
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé. W & G p. 81 as Vinca rosea L. "Maliku ruva."

Nerium indicum Mill.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Nerium oleander L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Ochrosia oppositifolia (Lam.) K. Schum.
Malé, Malé I., occasional near outer beach, Fosberg 36824. "Dumburi."
Malé; S. Mahlos. W & G p. 81 as Ochrosia borbonica Gmel. "Dhumburi", "Dumburi."

Plumeria obtusa L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Plumeria rubra L.
Malé; Kolumadulu. W & G as Plumeria acutifolia Poir. "Gulu sampa", "Semper Beddha." P. 81.

Thevetia peruviana (Pers.) Merr.
Malé. W & G p. 81 as Thevetia neriifolia Juss.? "Hinbatu."

Asclepiadaceae

Calotropis gigantea (Willd.) R. Br.
Malé, Malé I., common, Fosberg 36827. "Ruwa."
Malé. W & G p. 81. "Ruva", "Hudu ruva", "Rua."

Convolvulaceae

Convolvulus parviflorus Vahl
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; throughout the group. W & G p. 84. "Walu mirihi."

Evolvulus alsinoides L.
Malé; S. Mahlos; Haddumati. W & G p. 84. "Veo magu", "Meia limbo."

Hewittia bicolor W. & A.
S. Mahlos. W & G p. 84.

Ipomoea batatas (L.) Poir.
Malé; Addu; throughout whole group. W & G p. 83. "Oludukattala."

Ipomoea littoralis Bl.
Kolumadulu. W & G p. 84 as Ipomoea denticulata Chois.

Ipomoea pes-caprae (L.) Sweet
Malé; Goifurfehendu. W & G p. 84 as Ipomoea biloba Forsk. "Taburu", "Thaburu."

Ipomoea quamoclit L.
Malé. W & G p. 83. "Kudiraima-veyo."

Ipomoea tuba (Schlecht.) G. Don
Malé, Furannafuri I., very rare in Cordia-Pemphis thicket, sterile, Fosberg 36902.
Goifurfehendu; Addu. W & G p. 83 as Ipomoea grandiflora Lam.

Ipomoea turpethum (L.) R. Br.
Malé. W & G p. 83. "Kurifila."

Merremia dissecta (Jacq.) Hall.f.
Malé, Malé I., climbing in scrub at top of seaward beach, Fosberg 36839.

Trichodesma zeylanicum (L.) R.Br.
Malé; N. Mahlos; Goifurfehendu; Addu. W & G p. 83. "Malebu."

Borraginaceae

Cordia subcordata Lam.
Malé, Furannafuri I., abundant in thickets on very stony ground, rare on beaches, Fosberg 36905. "Kaani."
Malé; Goifurfehendu; Kolumadulu; Suvadiva. W & G p. 82. "Kani."

Messerschmidia argentea (L.f.) Johnst.
Malé, Kuda Bados I., occasional at top of beach, rare inland, Fosberg 36892. "Bori."
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; N. Mahlos. W & G p. 82 as Tournefortia argentea L.f. "Bori", "Mabori."

Solanaceae

<u>Capsicum</u> <u>frutescens</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956. Probably this species. Hot pepper sauce very widely used in Maldivian food.

<u>Capsicum</u> <u>minimum</u> Roxb.
Malé; Goifurfehendu; Kolumadulu; Mahlos; Miladumadulu. W & G p. 85. "Mirus."

<u>Datura</u> <u>metel</u> L.
Malé, Malé I., spontaneous in waste places, Fosberg 36842. "Hudu orani."
Malé; Miladumadulu; Kolumadulu; Addu. W & G p. 85 as <u>Datura</u> <u>fastuosa</u> L. "Orhani."

<u>Datura</u> <u>suaveolens</u> H. & B.
Malé. W & G p. 86.

<u>Nicotiana</u> <u>tabacum</u> L.
Malé; Mahlos; Miladumadulu. W & G p. 86. "Dumpai."

<u>Physalis</u> <u>minima</u> L.
Malé; Goifurfehendu; Kolumadulu; sparsely in the whole group. W & G p. 85. "Muraki."

<u>Solanum</u> <u>melongena</u> L.
Malé; Kolumadulu; Addu; cultivated in whole group. W & G p. 85."Bari","Kara."

Verbenaceae

<u>Clerodendrum</u> <u>indicum</u> (L.) Kuntze ?
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956. Probably this species.

<u>Clerodendrum</u> <u>inerme</u> (L.) Gaertn.
Malé, Malé I., occasional near outer beach, Fosberg 36825. "Dungeti."
Malé. W & G p. 89. "Dugeti", "Dugajde."

<u>Lantana</u> <u>mixta</u> L.
S. Mahlos; "all over the north of the Archipelago." W & G p. 87.

<u>Lippia</u> <u>nodiflora</u> L.
Malé, Malé I., very general in open places, Fosberg 36858. "hiri dati."
Malé; Kolumadulu; Addu. W & G p. 88. "Hunigunditila."

<u>Premna</u> <u>obtusifolia</u> R. Br.
Malé, Malé I., common in scrub at top of seaward beach, Fosberg 36835. "Dakanda."
Goifurfehendu; Suvadiva; N. Mahlos. W & G p. 88 as <u>Premna</u> <u>integrifolia</u> L. "Kude", "Gelavalie."

<u>Stachytarpheta</u> <u>jamaicensis</u> Vahl
Malé, Malé I., occasional in open places, Fosberg 36821. "Malémbu."
Malé. W & G p. 88 as <u>Stachytarpheta</u> <u>indica</u> var. <u>jamaicensis</u>.
"Malaembu", "Nunnay."

<u>Tectona</u> <u>grandis</u> L.
Malé. W & G p. 88.

<u>Vitex</u> <u>negundo</u> L.
Malé; S. Mahlos; Kolumadulu. W & G p. 88. "Dunnika."

Labiatae

<u>Anisomeles</u> <u>ovata</u> R. Br.
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; Addu. W & G p. 90.
"Muskotan", "Maskota."

<u>Leucas</u> <u>biflora</u> R. Br.
Malé; Suvadiva; Addu. W & G p. 90. "Veo miri", "Veo mirihi."

<u>Leucas</u> <u>zeylanica</u> (L.) R. Br.
Miladumadulu; "also in other islands where yams are cultivated."
W & G p. 90.

<u>Ocimum</u> <u>basilicum</u> L.
Malé; N. Mahlos; S. Mahlos; Goifurfehendu. W & G p. 89. "Gandakoli."

<u>Ocimum</u> <u>gratissimum</u> L.
Malé. W & G p. 89. "Fonitulá."

<u>Ocimum</u> <u>sanctum</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.
Malé; N. Mahlos. W & G p. 89. "Kulitulá", "Gai Kehabuli."

<u>Plectranthus</u> <u>zeylanicus</u> Benth.?
Malé; Haddumati; N. Nilandu. W & G p. 89. "Huvadukotun", "Huvaduka."

Scrophulariaceae

<u>Bacopa</u> <u>monnieri</u> (L.) Pennell
Malé; Miladumadulu. W & G p. 86 as <u>Herpestis</u> <u>monniera</u> H.B. & K.
"Veppila."

Bignoniaceae

<u>Tecoma</u> <u>stans</u> L.
Malé, Malé I., cultivated, seen but not collected, Fosberg in 1956.

Acanthaceae

<u>Barleria</u> <u>prionitis</u> L.
Malé; Miladumadulu; Goifurfehendu; Kolumadulu; "cultivated everywhere."
W & G p. 86. "Dai kurandu," "Ma tumba", "Hai kurudo."

Justicia procumbens L.
Malé. W & G p. 87.

Pseuderanthemum carruthersii Seem.
Malé, Malé I., cultivated, Fosberg 36878.

Pseuderanthemum carruthersii var. atropurpureum (Bull) Fosb.
Malé, Male I., cultivated, seen but not collected, Fosberg in 1956.

Ruellia ringens L.
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; Haddumati. W & G p. 86.
"Nita bodi", "Nitu badi."

Rungia parviflora Nees
Malé; Miladumadulu; Addu; "frequent in the group". W & G p. 87.

Rubiaceae

Borreria ocymoides (Burm.f.) DC.
S. Mahlos; "in many islands." W & G p. 76 as Spermacoce ocymoides Burm.f.

Guettarda speciosa L.
Malé, Malé I., occasional in scrub at top of seaward beach, Fosberg 36836. "Wuni."
Malé; S. Mahlos; Kolumadulu; "very common throughout the group." W & G p. 75. "Uni."

Hamelia patens Sw.
Malé. W & G p. 75.

Hedyotis biflora (L.) Lam.
Malé; Goifurfehendu; S. Mahlos; Kolumadulu; "throughout the group." W & G p. 75 as Oldenlandia biflora L. "Kudingaybelamaw,"Eyaganawatura", "Beem magu."

Hedyotis corymbosa (L.) Lam.?
Malé. W & G p. 75 as Oldenlandia corymbosa L.

Hedyotis umbellata (L.) Lam.
Malé, Malé I., common in grassy area on top of old fort, Fosberg, 36909; common in dense weedy sod back of beach, Fosberg 36857. "Em mudi."
Malé; S. Mahlos; Goifurfehendu. W & G p. 75 as Oldenlandia umbellata L. "Emmuli."

Morinda citrifolia L.
Malé, Furannafuri I., occasional in coconut plantation, Fosberg 36904. "Ahi."

Morinda citrifolia var. bracteata Hook.f.
Malé, Kuda Bados I., occasional in coconut plantation, Fosberg 36888. "Ahi."
Malé; Goifurfehendu; Kolumadulu; S. Mahlos. W & G p. 76. "Ahi."

Goodeniaceae

Scaevola sericea Vahl
Malé, Malé I., dominant in scrub at top of seaward beach, Fosberg 36834. "Magu."
Malé; Goifurfehendu; Kolumadulu; "the most numerous shrub in the group." W & G p. 79 as Scaevola koenigii Vahl. "Magu."

Compositae

Adenostemma viscosum Forst.
Malé; S. Mahlos; Kolumadulu; Goifurfehendu; Addu, W & G p. 77. "Foni-loli."

Ageratum conyzoides L.
Malé; Haddumati. W & G p. 77. "Kochché-fai."

Artemisia vulgaris L.
Malé. W & G p. 78. "Mirajjé Kochchefai."

Blumea membranacea DC.
Kolumadulu; Haddumati. W & G p. 77.

Eclipta alba (L.) Hassk.
Malé; Kolumadulu. W & G p. 77. "Kalukadili."

Emilia sonchifolia (L.) DC.
Malé, Malé I., common in dense weedy sod back of beach, Fosberg 36855. A dwarfed fleshy form found also on Ceylon beaches. "Hiri Kulla."
Malé; Goifurfehendu; in S. of Archipelago. W & G p. 78. "Hirikulla."

Lactuca polycephala Benth.
Goifurfehendu. W & G p. 78.

Launaea pinnatifida Cass.
Malé; Malé I., common in grassy area on top of old fort, Fosberg 36910. "Hula fila." Used as potherb.
Malé; Goifurfehendu; N. Mahlos. W & G p. 78. "Dandu filia", "Kadapi", "Kulla fila."

Synedrella nodiflora (L.) Gaertn.
Malé, Malé I., common locally in waste places, Fosberg 36851. "Mirihivan kandidi."

Tithonia diversifolia A. Gray
Malé. W & G p. 78. "Bodu-mirihi."

Tridax procumbens L.
Malé, Malé I., very common generally, Fosberg 36865. "Mavina."

Vernonia cinerea (L.) Less.
Malé, Malé I., common, Fosberg 36874. "Walu kafa."
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; common throughout group. W & G p. 76. "Walu kafa."

Wedelia biflora (L.) DC. ex Wight
Malé, Malé I., common in inner edges of scrub at top of seaward beach, Fosberg 36837. "Mirihi."
Malé; S. Mahlos; Goifurfehendu; Kolumadulu; common in entire group. W & G p. 77. "Mirihi."

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